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Evidence for a Perceptual Recalibration of Self-Control during Thermal Stress

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EVIDENCE FOR A PERCEPTUAL RECALIBRATION OF SELF-CONTROL DURING THERMAL STRESS

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Abstract

Introduction: Stress can negatively affect conscientiousness, decision making, behavior inhibition, and other examples of self-control. Environmental cold stress has been shown to curtail various aspects of cognitive performance, however the extent to which thermal stress may impact general measures of self-control is unknown. The purpose of the current dissertation is to understand how cold stress impacts executive functioning based self-control, the delay of gratification, state self-report self-control, and performance persistency; and whether variability in self-control failure can be predicted. **Method:** The current research explores the relationship between thermal stress and self-control across two studies. Cold stress was manipulated using cooling packs and direct blowing air. Thermal stress was subjectively measured using a Thermal Comfort Assessment questionnaire and objectively measured using ear and skin temperature along with skin conductance, respiration, and electromyographic measures of sympathetic reactivity. *Study 1:* Using a counterbalanced within-subjects design with two conditions, 50 participants performed the Arrow Flankers task and Stop-Signal task; which measure executive functioning based self-control. *Study 2:* Using a between-subjects design, 76 participants performed four tasks in a cold stress or comfortable condition. Participants completed a difficult drawing puzzle, a handgrip task, the State Self-Control Capacity Scale, and Monetary Choice Questionnaire; which measure performance persistency based self-control, self-report state self-control, and delay of gratification respectively. **Result:** *Study 1:* Cold stress did not impact executive functioning based self-control. *Study 2:* Cold stress did not impact performance persistency ability or the ability to delay gratification. However, cold stress did reduce individual's perception of their own self-report state self-control ability. Those with high and low trait self-control reported they felt less able to use self-control while cold, although performance was not affected. **Conclusion:** These

studies provide original evidence that we calibrate our perception of personal self-regulatory ability based on comfort, and that we recalibrate to fit thermally stressful situations.

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Table of Contents

Page

Table of Contents (Continued) Page

List of Tables

Page

List of Figures

List of Figures (Continued) Page

Introduction

A Brief Introduction

To a lesser or greater extent, thermal stress is experienced daily. There is a narrow temperature comfort band for the human body which changes constantly in accordance with the circadian rhythm, the environment, and activity. Modern conveniences and physiological mechanisms often limit the degree of discomfort, but occasions of thermal stress still exist, particularly in outdoor occupations. When individuals do become uncomfortable, performance on cognitive and physical tasks suffers. Despite this, the vast majority of conclusions made by psychologists assume a comfortable environment with little attention given to everyday environmental stress. Similarly, limited self-control is also experienced daily (Baumeister, Bratslavsky, Muraven, & Tice, 1998). Self-control is an integral part of daily decision making, conflict management, environmental adaptation, and allows us to resist impulses which conflict with long term goals (Pilcher, Morris, Donnelly, & Feigl, 2015). When self-control fails, individuals may cheat on their diet, relapse into addiction, or bypass safety procedure. As such, both thermal comfort and self-control are important topics for human factors psychology.

Although thermal comfort and self-control operate as dynamic human factors, relatively little is known about their relationship. In particular, prior research does not indicate how thermal stress may impact the individual elements of self-control such as persisting on a task or choosing large long term goals over small short term desires. However, research does suggest that the capacity to exercise self-control is limited by factors such as discomforting stress, although original research is needed to better understand this relationship (Heatherton & Wagner, 2011).

Cold Stress Physiology

Cold exposure is an effective and simple method of inducing stress in a controlled laboratory environment. Cold exposure produces a reliable physiological stress response with a relatively quick onset and offset (Van Orden, Benoit, & Osga, 1996). The physiological basis of cold stress stems from the human-thermal balance and endogenous homeostasis. Human-internal body temperature should be maintained (i.e., balanced) at about 98°F in its environment, although there is natural variability in accordance with the melatonin levels of the circadian rhythm (Yu & Reiter, 1992). In a case of a positive heat balance, body temperature rises in response to internal heat production and environmental heat introduction. If the body cannot cool itself through physiological or behavioral intervention to a point which balances internal temperature, heat stress (i.e., hyperthermia) will occur. In a case of a negative heat balance, body temperature drops in response to insufficient internal heat production and heat loss to the environment. If the body cannot warm itself through physiological or behavioral intervention to a point which balances internal temperature, cold stress (i.e., hypothermia) will occur (Parsons, 2014). In the current dissertation, cold stress is defined as the human physiological, psychology, and behavioral reaction to being cooled.

In the case of cold stress, the human body has two primary physiological mechanisms for correcting and maintaining the heat balance. The first mechanism is shivering and non-shivering thermogenesis (ST and NST). The human body increases striate skeletal muscle activity which results in internal heat production as a function of work. In periods of profound body cooling, the increased muscle activity creates a reciprocating coactivation of muscles at skeletal joints and a visible shaking can be observed – shivering thermogenesis (Hemingway, 1963).

However, muscle coactivation and thermogenesis commonly occur without visible shaking -- non-shivering thermogenesis -- resulting instead in less dexterous movement. The second physiological mechanism is peripheral vasoconstriction and vasodilation (PVC and PVD), often called cold-induced vasoconstriction (CIVC) when associated with a negative heat balance. During CIVC the muscular walls of the peripheral circulator system (e.g., hand and feet) constrict to put insulating distance between the epidermis and the blood of the arterioles, limiting the radiation of internal heat (Lopez, Sessler, Walter, Emerick, & Ozaki, 1994). As a result, the surface of the skin at these peripheral locations cools without heat loss from the blood, protecting internal temperature. However, CIVC is not a static state, the peripheral circulatory network can also cyclically dilate to insure damaging levels of cooling do not occur, a physiological cycle referred to as the hunting reflex (Warren, McCarty, Richardson, Michener, & Spindler, 2004). An understanding of the physiological response to cold allows for the possibility of measuring cold stress more objectively.

Measuring Cold Stress

Prior research has shown that cold stress can be indexed using objective measures of physiological changes and subjective measures of cold perception. Physiological methods include measuring body temperature directly, or measuring the underlying mechanisms related to the sympathetic stress response. Using the latter methodology, researchers may record muscle activity from electromyographic (EMG) electrodes to index shivering and non-shivering thermogenesis (Imbeault, Mantha, & Haman, 2013). The process of thermogenesis requires the constant use of energy stores, so researchers have also begun to look at indirect calorimetry as a measure of cold stress (Haman et al., 2002). However, such measures neglect the actual state of the body's heat balance. As an alternative objective method, researchers commonly measure body temperature directly. Because cooled skin temperature at the hands and feet (CIVC) are one of the most overt physiological responses to cold, reduction in hand skin temperature is often used to index cold stress (Goonetilleke & Hoffmann, 2009). Moreover, prior research has also suggested the use of mean skin temperature (also known as shell temperature) to index cold stress by calculating weighted averages of skin temperature from several body locations (Choi, Miki, Sagawa, & Shiraki, 1997). However, it should again be noted that skin temperature is subject to constant physiological adjustment in response to internal and external factors.

In addition to skin temperature measures, estimates of internal temperature (i.e., core temperature) have been proposed using a variety of methods and locations. Due to the thoracic pooling seen during peripheral vasoconstriction, internal temperatures near the heart and brain remain relatively stable under stress. As such, small deviations in internal temperature may be a more accurate measure of cold stress than measuring dynamic physiological responses which overcompensate to maintain homeostasis (Frank, Raja, Bulcao, & Goldstein, 1999). Rectal temperature, arterial temperature, or pill-based telemetry methods are often considered the gold standard in estimating core temperature; however, they remain taboo, too invasive, or too expensive for many studies (Moran & Mendal, 2002). As such, oral temperature and tympanic temperature are commonly seen as alternative methods. Oral temperature is recorded from the lingual artery underneath the tongue using a resistance temperature detector (RTD) based thermometer while tympanic temperature is recorded from the middle ear using an infrared thermometer. However, oral temperature is affected by eating and drinking, and both methods are susceptible to effects from physical activity, therefore certain protocols (e.g., limiting the participants eating, drinking, and movement once they enter the lab) must be put in place to ensure the accuracy of the measurement.

Subjective self-report measures of cold stress are also commonly seen in research and generally assess perception of thermal stress. Thermal perception and comfort can be influenced by clothing insulation, activity, acclimatization, in additional to environmental factors such as wind speed, humidity and temperature (Olesen, 1982). Despite this complex interaction, perception, comfort, and arousal are critical psychological factors that should be considered when thermal stress is present during a cognitive task (Hancock & Warm, 1989). To measure subjective thermal stress, Thermal Comfort Assessment scales (TCA) have been generically developed to fit their application, but most stem from the American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE) Sensation Scale (ASHRAE, 1966) and the Bedford comfort scale (Bedford, 1936). The ASHRAE sensation scale ranges from 1 (Cold) to 7 (Hot) with 4 representing neutral, while the Bedford comfort scale ranges from 1 (Much too cool) to 7 (Much too warm) with 4 representing comfortable. However, evolutions of the scale have included different ranges (1-9 or 1-5) to accommodate other responses (Parsons, 2002).

Because thermal stress is inherently stressful, cold stress can also be measured as a function of an objective physiological stress responses unrelated to temperature. Muscular tonus in the trapezius muscle as measured through electromyographical (EMG) activity has been shown to accurately index mental and physical stress (Lundberg et al., 1994). Fluctuations in amplitude of galvanic skin response as measured through skin conductance (SC) has been shown to accurately index stress comparably to norepinephrine levels and blood pressure (Storm et al., 2002). Also cardiac activity, including but not limited to heart rate and heart rate variability/interbeat interval (HRV or IBI) has also been shown to be a powerful tool for indexing stress (Hjortskov et al., 2004). HRV in particular has been shown to increase during high self-regulatory effort (Segerstrom & Nes, 2007). These physiological systems receive input directly from the sympathetic and parasympathetic braches of the autonomic nervous system and therefore act as a gauge of the physiological stress response (Ellis, Sollers III, Edelstein, & Thayer, 2008).

Performance during Cold Stress

The human body naturally places a high priority on maintaining core temperature. Indeed, physiological vasoconstriction increases the likelihood of frostbite in an effort to maintain visceral temperature. As a result, changes in cognitive performance during cold stress are not always accompanied by hypothermia, but still reflect the curtailing impact of the environment.

Meta-analytical studies of cognitive performance under warm and cold conditions have found that environmental temperature deviations of as little as 10°F were enough to hinder performance across a wide range of cognitive functions (Hancock, Ross, & Szalma, 2007; Pilcher, Nadler, & Busch, 2002). Furthermore, cognitive decrement followed the Yerkes-Dodson Inverted-U and Hancock-Warm Extended-U models of stress and performance, showing poor performance relative to intensity of the stressor in either direction (Hancock & Warm, 1989; Pilcher et al., 2002; Yerkes & Dodson, 1908). Within these findings, cold stress had a larger effect on cognitive performance than heat stress, and tasks related to reaction time were least affected.

Researchers have postulated two main theories for why cold stress impacts cognitive performance. One theory suggests that the negative impact of cold stress on higher-order cognitive performance is due to a distracting effect (Vaughan, 1977). Research using cold water immersion found that attention decreased immediately upon exposure to cold stress and did not decline as core temperature dropped (Cheung, Westwood, & Knox, 2007). Additional research used exercise to increase core temperature while in a cold environment and did not see an increase in attentional performance despite an increase in core temperature (Muller et al., 2011). Together, these studies suggest that attention is unrelated to core temperature, and instead related to cold discomfort.

The second theory suggests that physiological hyperarousal results in a speed-accuracy tradeoff (Hancock, 1986). Physiological research has shown that cold exposure encourages sympathetic nervous system activation which in turn stimulates the release of noradrenaline (Leppäluoto, Pääkkönen, Korhonen, & Hassi, 2005). In an applied study using soldiers, cold air was enough to encourage an adrenergic stress response which resulted in a quicker reaction time response but an increase in the number of performance errors; a speed-accuracy tradeoff (Benoit, van Orden, & Osga, 1996). This speed-accuracy tradeoff interpretation has implications for several higher order functions, including self-control. In the case of the military simulation, a state of fight-or-flight brought about quick adrenergic responses that were made before the decision was fully considered, a definition of impulsivity.

Self-Control and Impulse Control

Self-regulation -- the ability for an individuals to override, alter and interrupt impulsive behavior, or otherwise self-control a behavioral response -- is absolutely integral to everyday decision making and long-term functioning (Muraven, Tice, & Baumeister, 1998). Exercising self-control seems to rely on limited internal resources which undergo short-term depletion following use (Baumeister, Vohs, & Tice, 2007). This strength based model of self-control has been applied to all aspects of life, including drinking habits, personal diet, intelligent thought, rule following, and supports the basic idea of ego-depletion (Baumeister et al., 1998). Ego-depletion is the state of diminished internal resources and limited self-control following the exertion of self-control. Prior research has suggested that blood glucose may be an important chemical resources involved with ego-depletion, however the extent of glucose's role in self-control is often debated (Hagger, Wood, Stiff, & Chatzisarantis, 2010; Vadillo, Gold, & Osman, 2016). In the wake of a failure to replicate some ego-depletion studies, prior research has also suggested that self-control may be a function of willpower. This theory proposes that a depletion of psychological resources rather than depletion of physiological resources results in impulsiveness (Job, Dweck, & Walton, 2010). Regardless of the mechanism, poor self-control generally occurs in response to coping with stress, and a combined psychophysiological mechanism is likely at play (Pilcher & Morris, 2016).

Although the topics explored is cold stress research are diverse, the effect of thermal stress on self-control is still unknown (Morris, Pilcher, & Powell, 2017). One investigation showed that during a warfare simulation in which soldiers were tasked with identifying and attacking hostile targets, soldiers subjected to cold stress demonstrated a significantly higher number of unprompted attacks without waiting for a hostile prompt (Van Orden et al., 1996). This finding could be explained in terms of self-control failure, but the authors did not explicitly measure self-control. Other research investigating warm thermal stress and affect has shown that thermal discomfort clearly increases aggression (Anderson, 1989). Aggressive behavior is mediated by self-control, therefore the presence of aggression may be explained in terms of failed self-control. Indeed, the Impulsive/Premeditated Aggression Scale (IPAS) has been developed to use aggressive behavior as part of its self-control and impulsivity paradigm (Stanford et al., 2003). These studies point to a self-control cold-stress relationship, however the author of this dissertation is unaware of any research that has looked at cold stress and self-control directly.

Despite the lack of self-control research within the field of cold stress, cold stress may still play a major role in self-control. The process of physiological thermal genesis (shivering and non-shivering) requires metabolic resources such as blood glucose. Research on the role of circulatory glucose and muscle glycogen in shivering thermogenesis found the oxidation of plasma glucose increased by 138% and muscle glycogen by 109% (Haman et al., 2002), effectively using a portion of the theorized self-regulation resource. This would suggest that prolonged cold stress exposure could eventually result in behaviors associated with ego-depletion. In addition to thermogenesis, the endurance of physical discomfort has also been shown to require self-regulatory resources (Muraven et al., 1998; Zinser, Baker, Sherman, & Cannon, 1992). As it concerns self-regulation, the cold pressor test (i.e., hand in ice bath) has commonly been used as a methodology for inducing physical discomfort in hundreds of scientific studies (Flora, Wilkerson, & Flora, 2003; Harris & Rollman, 1983). This use of cold stress would imply that cold exposure is an ideal candidate for a physical stressor capable of inducing ego-depletion and altering self-control reliant behaviors. Cold stress from a cold pressor does differ from cold stress from body cooling in that it produces discomfort from pain (nociception) rather than discomfort from a cooling sensation (thermoception). However, if cold stress from body cooling does impact self-regulation, it is likely that thermal comfort has been an unknown mediating variable in many self-control studies. Indeed, research has shown that intellectual performance is sensitive to both cold stress, perhaps because cold stress leads to degraded self-control which in turn limits intellectual performance (Schmeichel, Vohs, & Baumeister, 2003). Pilcher et al. (2002) concluded their meta-analysis on cold stress and cognitive performance by noting that cold stress has the most negative effect on reasoning tasks, a cognitive component often connected to self-control (Baumeister, Sparks, Stillman, & Vohs, 2008). In consideration of all these findings, it is reasonable that cold stress could limit self-control.

Measuring Self-Control and Impulse Control

Prior research suggests that self-control and impulse control can be measured using a variety of methods. However, each method may measure a different aspect of the overall self-control construct. One meta-analytic study on the convergent validity of self-control measures identified three main methodological categories of self-control measures (Duckworth & Kern, 2011). The first category of measures are executive function tasks, in which top-down control is exerted over lower-level cognitive processes. Executive function tasks often take the form of choice reaction time tasks which require the individual to resist the impulse to respond to stimuli under a certain condition. Two examples of this include the Arrow Flanker task and the Stop-Signal task, both of which require the user to perform a choice reaction time task, then suddenly cease responding if a specific symbol appears (Eriksen & Eriksen, 1974; Logan, Schachar, & Tannock, 1997). Researchers have also suggested that the Stroop Test meets the criteria of an executive functioning measure of impulse control by requiring individuals to override responses in order to substitute alternate responses (MacLeod, 1991; Stroop, 1935; Wallace & Baumeister, 2002). During the Stroop Color-Word Test, individuals must correctly respond to a series of stimuli in accordance with their ink color while inhibiting the previously overlearned response of reading the word, exercising executive impulse control (Duckworth & Kern, 2011).

The second category of measures are delay of gratification tasks, in which urges of instant gratification must be suppressed (Duckworth & Kern, 2011). Delay of gratification tasks often take the form of hypothetical choice or real choice tasks which require the individual to choose between smaller rewards sooner or larger rewards later (SSLL paradigm). Two examples of this include the classic Marshmallow Test, in which children resist the urge to eat a marshmallow sooner in return for two marshmallows later (Mischel, Shoda, & Rodriguez, 1989). As well as the delayed reward discounting tasks, where individuals choose between a small cash reward sooner or a larger cash reward in a certain number of days (Kirby & Maraković, 1996; Kirby, Petry, & Bickel, 1999).

Research has also suggested measures of performance persistency, such as maintaining difficult cognitive or physical effort over a period of time, as a type of delay of gratification tasks. In this case, individuals delay gratification by continuing to do something difficult. In one study, researchers using both a control group and an ego-depleted group timed how long participants would attempt to solve a difficult or unsolvable puzzle (Baumeister et al., 1998). Results showed that participants who previously had their self-control manipulated by an ego-depletion task gave up on completing the puzzle sooner. Other studies have shown that persistence on a physical effort task, similar to cognitive persistence on a puzzle, is a measure of self-control. Using a continuous handgrip task, participants who experienced prior self-control were found to give up on the task sooner (Muraven et al., 1998). Although many ego-depletion studies have come under fire due to replication issues, the methodology used is separate self-control studies not relying on an ego-depletion explanation for the effect (Aarts, Custers, & Marien, 2008).

In recent years, task persistence has also been explored as part of the grit literature, which views perseverance as a sort of long-term self-control (Duckworth, Peterson, Matthews, & Kelly, 2007; Duckworth & Seligman, 2005). Grit research focuses on personal cognitive traits that accompany those who endure long tem difficult tasks willingly. Because much of the grit research is relatively new, grit is not addressed in many of the seminal self-control studies. Albeit independent from self-control, grit has been shown to correlate with self-control and is most commonly measured using the Grit Scale (Duckworth et al., 2007). However, it should be noted that grit overlaps with self-control large as a result of conscientiousness (Duckworth & Gross, 2014; Fite, Lindeman, Rogers, Voyles, & Durik, 2017).

The third category of measures are self-report questionnaires, in which self-control is estimated using a series of personality trait items or state items (Duckworth & Kern, 2011). Although, performance persistency is often considered a separate methodological category of self-control, making self-report questionnaires a forth category according to current numeric nomenclature. These scales come in two forms, one assessing trait (long-term personality) and the other assessing the state (immediate feelings). Three common trait scales seen in prior research include the Brief Self-Control Scale, the Eysenck Impulsiveness Scale, and the Barratt Impulsiveness Scale, which include items about doing and saying things without thinking and subdivides the measure into risk-taking, non-planning behavior, and impulsive tendencies (Eysenck & Eysenck, 1978; Eysenck, Easting, & Pearson, 1984; Patton & Stanford, 1995; Tangney, Baumeister, & Boone, 2004). One of the few scales seen in literature that is used to assess self-control state is the State Self-Control Capacity Scale, which includes items about wanting to give up, feeling drained, and the perceived ability to resist temptation (Christian & Ellis, 2011; Thau & Mitchell, 2010; Twenge, Muraven, & Tice, 2004).

Research has also explored the possibility of using psychophysiological measures to index self-control. Prior research has suggested that heart rate variability can be a sensitive indicator of emotional regulation and cognitive inhibitory mechanisms (Ingjaldsson, Laberg, & Thayer, 2003). One study found that an ego-depletion task increased heart rate variability and predicted how long an individual would persist on solving difficult and impossible problems (Segerstrom & Nes, 2007). In this study, heart rate variability reflected the use of self-control, not self-control ability. Another study found that heart rate variability and blood pressure were correlated with the self-report ability to regulate and control behavior, but only in males (Allen, Matthews, & Kenyon, 2000). The extent to which other physiological measures can be used to predict self-regulation, especially those related to stress, is still unknown.

Purpose and Hypotheses

The effect of thermal stress on many physical and mental performance measures is well documented, however the effects of cold stress on self-control is relatively unknown. Prior research suggests thermal discomfort will result in ego-depletion and limit the ability to self-regulate. This question is explored across two studies, however the hypotheses reflect the general thesis and not the independent studies. The purpose of this dissertation is to discover whether cold stress can limit self-control and whether objective and subjective measures of cold stress can predict self-control degradation. Self-control is assessed using four methodological categories, each measuring a unique aspect of self-regulatory ability. These methods of assessing self-control have not been used in a cold stress research. A combination of self-report and physiological indices are used in tandem with self-control performance in an attempt to predict self-control failure.

Cold will limit self-control

Hypothesis 1a) Executive functioning will be assessed using the Arrow Flanker and Stop-Signal tasks, which require the participant to suddenly cease an overlearned reaction response. Cold participants are expected to show a greater number of false positive responses (i.e., responding after being signaled to stop) during the executive functioning tasks compared to when they are comfortable, which would suggest limited self-control. *Hypothesis 1b)* Perceived self-control ability in a given moment will be assessed using a self-report state self-control scale. Cold group participants are expected to score lower on the state self-report questionnaire which would suggest lower perceived self-control due to cold stress. *Hypothesis 1c)* The ability to delay gratification when offered an award will be assessed using a monetary choice questionnaire. Cold group participants are expected to show a greater preference for smaller rewards sooner instead of waiting for a larger long term rewards. A tendency towards short term gains would suggest a state of impulsiveness due to cold stress. *Hypothesis 1d)* Performance persistence is assessed using a handgrip task and an impossible puzzle task. Cold group participants are expected to give up sooner on the two persistence tasks which would suggest limited self-control ability. Specifically, cold participants are expected to be unwilling to apply high levels of effortful force to the handgrip and unwilling to make as many attempts at a difficult puzzle compared to those in the comfortable group.

Stress measures will predict self-control failure

Hypothesis 2a) Self-reported cold-perception and cold-related discomfort are both expected to predict the individual degree of self-control decrement across the four categories of self-control. Based on results from a previous thesis, cold perception is expected to be the better of the two predictors (Morris & Pilcher, 2016). *Hypothesis 2b)* Objective measures of skin temperature and internal temperature are expected to predict the individual degree of decrement across the four categories of self-control. Because cold perception is more closely related to skin temperature than internal temperature, skin temperature is expected to be the better of the two predictors. *Hypothesis 2c)* Muscle tone, skin conductance, respiration, and cardiac activity are expected to predict the individual degree of self-control decrement across the four categories of self-control. Consistent with general measures of stress, increased skin conductance, increased muscle tone, increased breaths per minute, and heart rate variability should behave like a stress index after accounting for baseline levels. In this case, an increased sympathetic response should index an increase in thermal stress and a decrease in self-control if the two are connected.

Methods

Study 1 (Methods)

Participants

56 participants completed the study. Due to technical difficulties during the session, data from 3 of those participants could not be used. The cold first condition included twenty-four participants (16 females and 8 males) with an average age of 19.54 years (*SD* = 1.31). The comfortable first condition included twenty-six participants (9 females and 17 males) with an average age of 19.35 years (*SD* = 1.06). Participants reported on average as having Good to Excellent physical and mental health. This study was approved by the Clemson University Institutional Review Board prior to any data collection. Participants involved in the study read over the study description and were given the opportunity to ask questions before signing the informed consent form. All procedure took place during one study session.

Participants were recruited from undergraduate psychology courses at Clemson University using the SONA System Human Subject Pool Management Software. Participants who completed the study were awarded research participation credit in their class. The SONA System informed participants that they must arrive at the laboratory wearing (or carrying) gym shorts, running shoes, and a short-sleeve cotton t-shirt, and that they must attempt to get a full night of sleep the night before the study. Participants who did not meet this requirement were rescheduled for another time. Criteria for data inclusion included the volunteer's status as a Clemson University student, having good mental and physical health, and being between the ages of 18-30. No participant chose to leave the study before the completion of the testing.

Setting and Apparatus

The study was conducted in an 880 square foot room in Brackett Hall on Clemson University's main campus. The room contained all tasks and equipment required for the study. The room was controlled and monitored for temperature and humidity using the in-room independent climate control system and separate air thermometer.

Materials and Equipment

Self-control Measures

Two reaction based executive function tasks were used to measure self-control, the Arrow Flankers task, and the Stop-Signal task (Duckworth & Kern, 2011). Both tasks were performed on a seven inch Nexus 7 tablet running PenScreenSix cognitive task software (v2.1b, Mobile Cognition Ltd; Edinburgh, Scotland) in a counterbalanced order. Both tasks took approximately 5 minutes to complete. The Arrow Flankers task (Eriksen & Eriksen, 1974; Fjell et al., 2012) presented a set of five symbols on the screen at a time **(Figure 1)**. The central symbol (the target), is always an arrow that is pointing to the right or the left. The other four symbols (the flanker symbols) are either congruent (pointing in the same direction as the target); incongruent (pointing in the opposite direction to the target); neutral (squares); or suppressors (X's). All four flanker symbols are always the same in a set. The goal is to press a left or right on-screen soft button which corresponds to the direction of the central target arrow as quickly as possible. If the flankers are X's, no response should be made. After the participant responds (or does not respond) to the set, the next set of symbols (i.e., the next trial) appears after 2 seconds. The researcher gave participants directions and a printed version of the task before the testing period. The printed version showed all the possible symbols and the research explained how the participant should respond to each. Participants were considered trained once they repeated back to the research what to do in each instance. In total there were 112 trails presented during each testing period. The mean time for correct responses, and number of false positive responses to the suppressor (X's) are recorded.

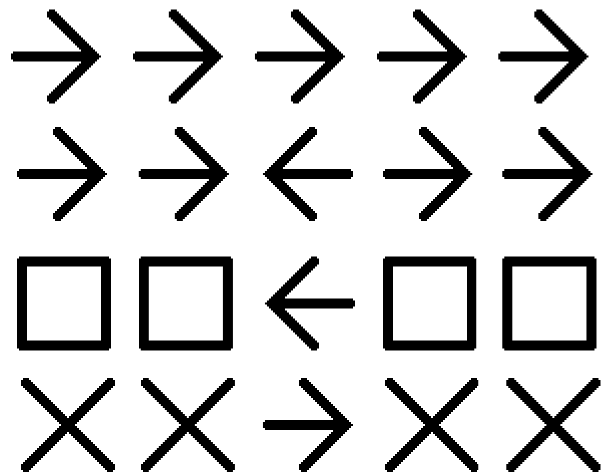

Figure 1: The four sets for the Arrow Fankers task

The Stop-Signal task (Bartholdy, Dalton, O'Daly, Campbell, & Schmidt, 2016; Logan et al., 1997) presented a fixation point for 500 ms, followed by a letter stimulus (either an X or an O) **(Figure 2)**. Participants must press a left on-screen soft button for an X or a right on-screen soft button for an O as quickly as possible. On 25% of the trials the letter appeared, then after a short delay (detailed below), two horizontal red lines appeared superimposed over the letter (the stop signal). When a stop-signal appears, the user should not respond to the stimulus. The time between the appearance of the letter and the appearance of the stop-signal is referred to as the stop-signal delay (SSD) and varies in increments of 50 ms. The SSD is initially 250 ms, and increases by 50 ms each time the user incorrectly responds to a letter with a stop signal (making the task easier on the next stop-signal trial) and decreases by 50 ms if the subject successfully withholds the response (making the task harder). After the participant responds (or does not respond) to symbol, the next fixation point and symbol (i.e., the next trial) appears after 2 seconds. The researcher again gave participants directions and a printed version of the task before the testing period. Participants were considered trained once they repeated back to the researcher what to do in each instance. In total there were 113 trials presented during each testing period. The mean time for correct responses, the mean SSD, the number of errors, and number of false positive responses to the stop signal are recorded.

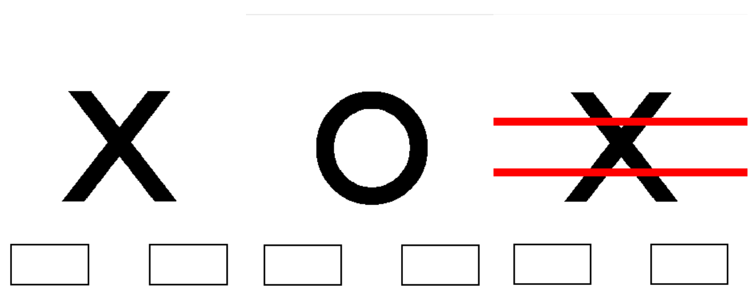

Figure 2: The two symbols and an example of the stop-signal for the Stop-Signal task

Research Chair

Three large plastic packs filled with a freezable material (FlexiFreeze, Mequon, WI) were placed on a reclining chair and used as the cold stressor during the cold condition **(Figure 3)**. The freezable liquid acted as a heat sink to remove heat from the surface of the participant's back and legs (Morris & Pilcher, 2016). The packs were removed from the chair after each participant and refrozen in a refrigeration unit before the next participant. During the comfortable condition the cooling packs were not present. Piot testing showed that participants quickly returned to feeling comfortable in the chair after the cold pack were removed.

Figure 3: The research chair prepared for the cold condition

Tympanic Temperature

Internal body temperature was estimated using an infrared tympanic thermometer **(Figure 4)**. A Thermoscan 5 ear thermometer (Braun; Kronberg, Germany) was placed in the participant's ear and used to record the temperature of the tympanic membrane (Parsons, 2014). The instrument was placed against the participants left ear for five seconds and was protected using a sanitary lens cover.

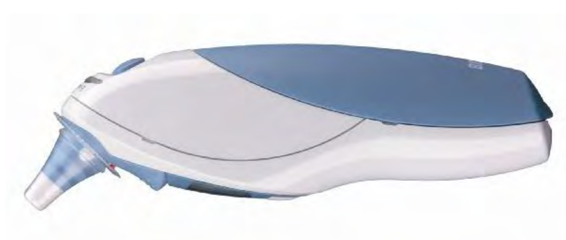

Figure 4: Infrared tympanic thermometer

Thermocouple Data Logger

Physiological vasoconstriction was monitored using a portable multi-channel real-time data logger (Grant Squirrel SQ2010; Grant Instruments; Royston, UK) with insulated thermocouple **(Figure 5)**. The unit logged skin temperature at 1.0 Hz using a Type K chromel-alumel thermocouple from the back of the non-dominant hand (Parsons, 2014). A female researcher applied the thermocouples to female participants. The thermocouple was secured to the participants using breathable medical tape. The thermocouple remained on the participant throughout the entirety of a study session.

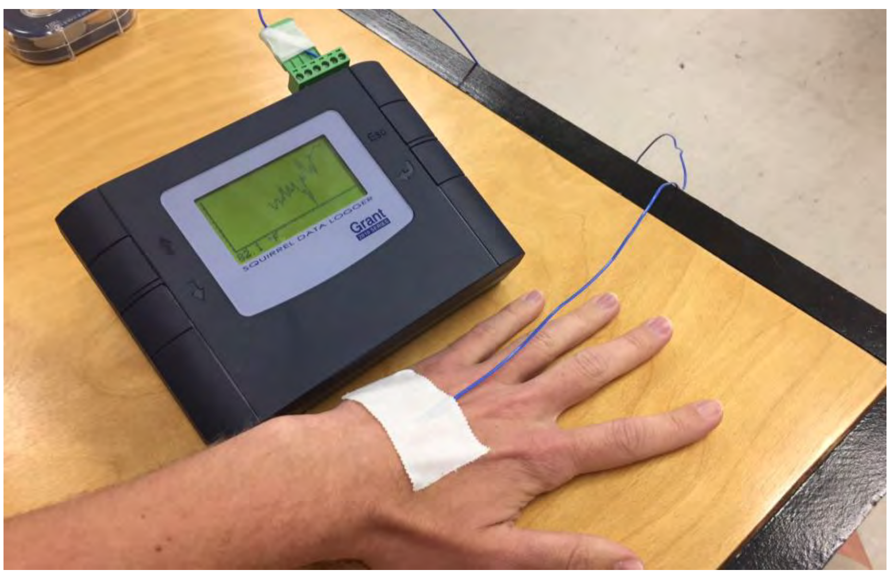

Figure 5: Skin temperature data logger

Physiological Data Logger

Several psychophysiological measures were digitally recorded using non-invasive surface sensors from a ProComp Infiniti biosensoring system (Thought Technologies; Montréal, Canada) **(Figure 6)**. To record cardiac activity, the system used photoplethysmography to index interbeat interval (IBI) from a single blood volume pulse oximeter sensor on the index finger of the non-dominant hand (Segerstrom & Nes, 2007). The small sensor (20mm x 34mm x 10mm) was attached to the fingertip using an adjustable Velcro band and recorded at 2048 Hz. To record muscle tension, the system used electromyography (EMG) to index muscle tonus from the trapezius muscle on the non-dominant side (Lundberg et al., 1994). The self-adhesive surface triode electrode (20mm spacing, silver silver-chloride) was attached to the central belly of the muscle and recorded at 256 Hz. To record respiration, the system used a sensitive strain gauge to index thoracic respiration rate through relative amplitude (Wuyts, Vlemincx, Van Diest, & Van den Bergh, 2017). An adjustable Velcro band was secured around the middle of the rib cage with the sensor at the sternum and recorded at 256 Hz. To record electro dermal activity, the system used skin conductance (SC) to index sympathetic eccrine gland activation from the middle and pinky fingers of the non-dominant hand (Pennebaker & Chew, 1985). The two sensors (20mm electrode pads) were attached between the medial and distal knuckles on the palmer side using an adjustable Velcro band and recorded at 256 Hz. A female researcher applied all sensors to female participants.

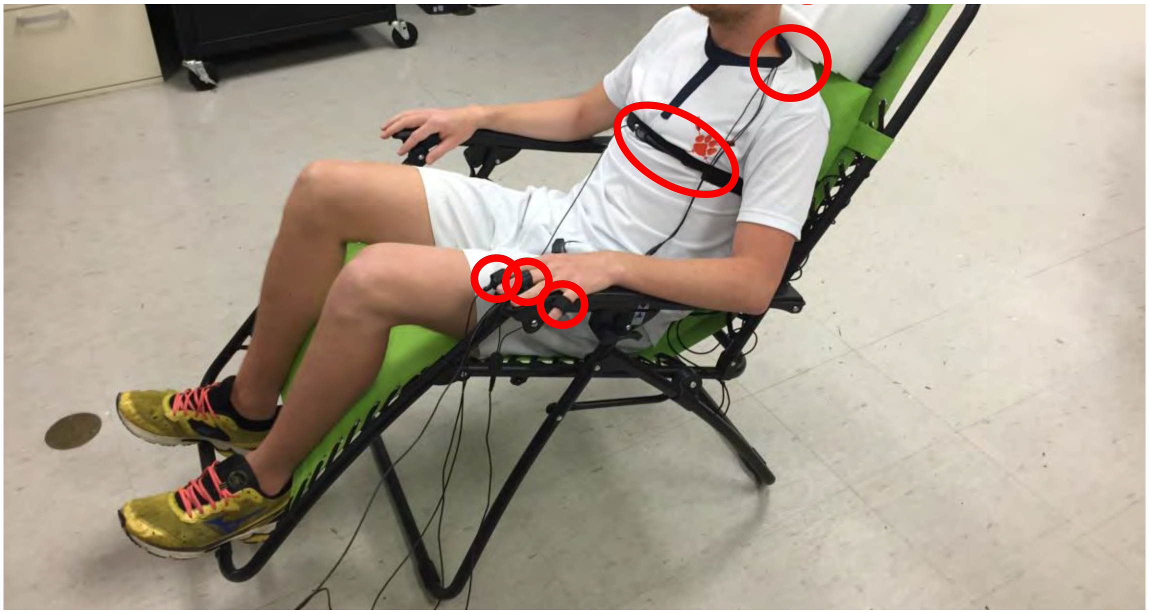

Figure 6: Sensor locations

Subjective Measures

Three subjective questionnaires were used periodically throughout the study. The Stanford Sleepiness Scale and Thermal Comfort Assessment after each task, and the Pittsburg Sleep Quality Index at the beginning of the study. Participants reported current subjective feeling of sleepiness using the Stanford Sleepiness Scale (SSS) (Hoddes, Dement, & Zarcone, 1971) **(see Appendix A)**. Lack of arousal from circadian rhythms or sleep deprivation can impact cognitive performance and was monitored to control for variability (Di Stasi, Catena, Canas, Macknik, & Martinez-Conde, 2013). The Likert scale ranged from 1, in which the participant was feeling active, vital, alert, and wide awake; to 7, in which the participant was no longer fighting sleep, the sleep onset was likely to occur soon, and was having dream-like thoughts.

Participants reported subjective feeling of thermal sensation and discomfort using the Thermal Comfort Assessment (TCA) (Parsons, 2002) **(see Appendix C)**. The questionnaire asked two questions pertaining to feelings of being too hot or too cold (Memon, Chirarattananon, & Vangtook, 2008). The first question was answered using a Likert scale ranging from 1, feeling very hot; to 9, feeling very cold; with 5 representing neutrality. The second question was answered using a Likert scale ranging from 1, feeling very comfortable; to 5, feeling very uncomfortable.

Participants also reported subjective sleep habits information using the Pittsburg Sleep Quality Index (PSQI) (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) **(see Appendix B)**. The questionnaire assesses usual sleep habits during the past month to index quality and patterns of sleep. The PSQI differentiates sleep quality by measuring seven components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction.

Design

Study 1 used a counterbalanced within-subjects design with two conditions, testing while cold and testing while comfortable **(Table 1)**. Participants completed both conditions, but were randomized as to which condition they would complete first, cold first or comfortable first. The first time they completed the tasks was always referred to as Time 1, the second time was Time 2. Before Time 1 participants completed a five minute physiological vanilla baseline while comfortable, followed by a relaxation period in their given condition. A vanilla baseline is any minimally demanding/engaging task that requires the participant to do more than simply sitting silently, and has been shown by Fishel and colleagues to be a good representative baseline when making physiological comparisons (Fishel, Muth, & Hoover, 2007). Between Time 1 and

Time 2 the participant was given a five minute adjustment period to minimize the effect of the previous condition.

Table 1: Study 1 timeline

		Time 1			Time 2	
Cold First Condition	Setup and Baseline	Cold Relaxation	Tasks	Adjustment	Comfortable Relaxation	Tasks
Comfortable First Condition	Setup and Baseline	Comfortable Relaxation	Tasks	Adjustment	Cold Relaxation	Tasks
		5 min	10 min	5 min	5 min	10 min

Reliability Measures

Research staff members, both undergraduate and graduate students, were fully trained in study procedure prior to participant testing. All study procedure descriptions were written out prior to testing to ensure each participant received the same instructions and information **(see Appendix D)**. A researcher monitored participants throughout the session and recorded any problems that occurred for the purpose of data integrity **(see Appendix E)**.

Procedure

Individuals who were interested were scheduled for a 75 minute timeslot. Once they arrived, participants were given the chance to have questions answered before they signed the informed consent and began any procedures. Once signed, basic demographic information was taken which included general mental and physical health questions **(see Appendix F)**. After the demographics form, the participants then filled out a copy of the PSQI to assess general sleep habits.

After the demographic survey and PSQI were completed the physiological equipment was attached. The temperature thermocouple was connected to a portable data logger and attached to the back of the participant's non-dominant hand using breathable medical tape. After using an alcohol swab and skin prep gel to clean the fingers, the skin conductance sensor and BVP sensor were then snuggly fit on the pinky, middle, and index fingers. An alcohol swab and skin prep gel were again used to clean the area over the the trapezius muscle and the EMG sensor was attached between the shoulder and neck. The respiration sensor was snuggly fit around the middle of the ribcage. Attaching all the sensors took approximately five minutes. After all the sensors had been attached, temperature was taken from the ear, sleepiness was assessed using the SSS, and thermal comfort was assessed using the TCA. Taking the temperature, sleepiness, and thermal comfort scores took approximately one minute.

After the participants completed the subjective assessment, they were carefully seated in the research chair with special attention put towards not moving the sensors. During this point in the study there were no cooling packs placed on the chair. Once in the chair, the participants sat upright and quietly read an article for five minutes while the physiological equipment recorded a vanilla baseline (Fishel et al., 2007). After the baseline period, temperature was taken from the ear, sleepiness was assessed using the SSS, and thermal comfort was assessed using the TCA, each one time.

After the baseline period was completed the participants then started their randomly assigned condition. If the participant was assigned to the cold first condition, three ice packs were placed on the research chair to create a cold stressor. If the participant was assigned to the comfortable first condition, no ice packs were placed on the research chair and the chair remained at room temperature. The angle of the chair back was then slightly reclined backwards 30° and the participant was instructed to close their eyes and relax for five minutes. This is referred to as the relaxation period, and was used as a time to introduce the thermal condition. Previous thesis research has shown that five minutes is an effective period for cooling (Morris & Pilcher, 2016). After five minutes of relaxation, temperature was taken from the ear, sleepiness was assessed using the SSS, and thermal comfort was assessed using the TCA.

After the relaxation period was completed, and while the participant was still seated, they then performed the two cognitive tasks (Arrow Flankers and Stop-Signal) in a counterbalanced order as part of Time 1. The researcher showed the participant a printed form of the first task and explained how they should respond under each circumstance. Once the participant confirmed that they understood the first task and were comfortable starting, they were given the first task to complete on the tablet. Once the first task was complete, temperature was taken from the ear, sleepiness was assessed using the SSS, and thermal comfort was assessed using the TCA. After the first task was completed, the participants then performed the second of the two cognitive tasks (Arrow Flankers or the Stop-Signal). The researcher showed the participants a printed form of the second task and explained how they should respond under each circumstance. Once the participant confirmed that they understood the second task and were comfortable starting, they were given the second task to complete on the tablet. Once the second task was complete, temperature was taken from the ear, sleepiness was assessed using the SSS, and thermal comfort was assessed using the TCA. This point marked the completion of the Time 1 period.

After both of the Time 1 cognitive tasks were completed, participants were given a five minute adjustment (i.e., warm up) period before starting Time 2 tasks. For those participants in the cold first condition, this involved the cold packs being removed from the chair and them sitting in the chair without cold stress. For those participants in the comfortable first condition, this involved them continuing to sit in the chair without the cold packs. No cold stress was present in either condition during the adjustment period. After the completion of the five minute adjustment period, participants assigned to the cold first condition started Time 2 by remaining in the chair without cold stress and again being instructed to close their eyes and relax for five minutes. Participants assigned to the comfortable first condition started Time 2 by having the ice packs placed on their chair and again being instructed to closed their eyes and relax for five minutes. After five minutes of relaxation, temperature was taken from the ear, sleepiness was assessed using the SSS, and thermal comfort was assessed using the TCA.

Time 1 and 2 were procedurally identical. After the second relaxation period was completed, and while the participant was still seated, they then performed the two cognitive tasks. After each task was completed, temperature was again taken from the ear, sleepiness was assessed using the SSS, and thermal comfort was assessed using the TCA. After the tasks were completed for both conditions, the session was considered complete.

Data Analysis

Data was organized and analyzed using Microsoft Excel spreadsheets and the IBM SPSS 22 statistical package. The independent variable being manipulated was the participant's level of thermal stress. Cold stress was measured using estimated internal temperature from the tympanic membrane, skin temperature from the back of hand, the TCA, SSS arousal, and the level of physiological stress response. The dependent variable was the participant's performance on the self-control measures. A 2 (*condition*: cold first, comfortable first) X 3 (*time*: baseline, Time 1, Time 2) mixed ANOVA was used to assess variability in cold perception, thermal comfort, arousal, and internal temperature. A 2 (*condition*: cold first, comfortable first) X 2 (*period*: relax, task) mixed ANOVA was used to assess variability in the physiological measures. And a 2 (*condition*: cold first, comfortable first) X 2 (*time*: Time 1, Time 2) mixed ANOVA was used to assess variability in Arrow Flankers and Stop Signal performance.

Self-Control Measures

The performance measure of the Arrow Flankers task is the number of false-positive responses made across all trials (Wilkowski, Robinson, & Troop-Gordon, 2010). False positive responses include cases when the participant made any response when the flanking symbol was an X. More false-positive responses are associated with an inability to control a behavior and therefore lack of self-control (Fjell et al., 2012). In much the same way, the performance measure of the Stop-Signal task is the number of false-positive responses made across all trials. False positive responses include cases when the participant made a response when the stop-signal symbol was present. More false-positive responses is associated with an inability to control a behavior and therefore lack of self-control (Bartholdy et al., 2016).

Control Variables

The performance measure for the SSS was the participant's subjective sense of sleepiness/arousal as indicated on a 7-point Likert scale. Self-perceived sleepiness data is associated with momentary arousal (Di Stasi et al., 2013). Participants indicating sleepiness scores at a 1 (i.e., alert or wide awake) are considered more alert/aroused than those at a 3 (i.e., responsive but not fully alert). The TCA performance measure is the participant's subjective sense of thermal comfort on a 5-point Likert scale and thermal perception on a 9-point Likert scale. Higher subjective TCA scores for discomfort and perception are associated with higher thermal stress (Memon et al., 2008).

Temperature Measures

Participant's internal body temperature was taken via infrared measurement from the tympanic membrane of the ear in degrees Fahrenheit. Lower internal temperature compared to baseline is associated with more thermal stress. The thermocouple data logger provided continuous skin temperature from the back of hand in degrees Fahrenheit at a sample rate of 1Hz. Lower hand skin temperature compared to baseline is also associated with more thermal stress (Memon et al., 2008).

Physiological Measures

Physiological measures were recorded with the ProComp Infiniti biosensoring system and used to objectively measure the psychophysiological stress response. Higher heart rate and an interbeat interval (IBI) LF/HF ratio above one is associated with more physiological stress. The LF/HF ratio was calculated using the ratio of LF power (low frequency heart rate variability) to HF power (high frequency heart rate variability) and indicates a sympathetic nervous system and parasympathetic nervous system activation balance as the value nears one (Segerstrom & Nes, 2007). LF/HF ratio was analyzed using advanced heart rate variability analysis software (Kubios HRV v2.2, Biosignal Analysis and Medical Imaging Group; Kuopio, Finland) on the Matlab platform (MathWorks, Inc.; Natick, MA). Increased surface EMG activation from the trapezius muscle compared to baseline is associated with more physiological stress (Lundberg et al., 1994). Increased skin conductance compared to baseline was associated with more physiological stress (Pennebaker & Chew, 1985).

Study 2 (Methods)

Participants

77 participants completed the study. Due to technical difficulties during the session, data from 1 of those participants could not be used. The cold group included thirty-eight participants (24 females and 14 males) with an average age of 19.50 years (*SD* = 0.93). The comfortable group included thirty-eight participants (21 females and 17 males) with an average age of 19.50 years (*SD* = 1.06). Participants reported on average as having Good to Excellent physical and mental health. Participants in Study 1 did not participate in Study 2. This study was approved by the Clemson University Institutional Review Board prior to any data collection. Participants involved in the study read over the study description and were given the opportunity to ask questions before signing the informed consent form. All procedures took place during one study session. Participant recruitment, attrition protocol, clothing standardization, and inclusion criteria was identical to Study 1.

Setting and Apparatus

Study 2 was conducted in the same space as Study 1. The room contained all tasks and equipment required for the study. The room was controlled and monitored for temperature and humidity using the in-room independent climate control system and separate air thermometer.

Materials and Equipment

Self-control Measures

Four tasks (two performance tasks and two questionnaires) were used to measure self-control; the handgrip task, the tracing puzzle task, the State Self-Control Capacity Scale, and the Monetary Choice Questionnaire. The handgrip task (E. Miles et al., 2016; Muraven et al., 1998) was used as a physical performance persistency task. To perform the task, the participants were given a metal-digital hand dynamometer (Neulog, Scientific Educational Systems; Israel) to hold in their dominant hand **(Figure 7)**. The participants were then instructed to squeeze that grip as long and as hard as they could with their elbow at a right angle. Participants were scored based on how hard the grip was held across two minutes. The researcher explained the directions and demonstrate how to hold the handgrip during the training period.

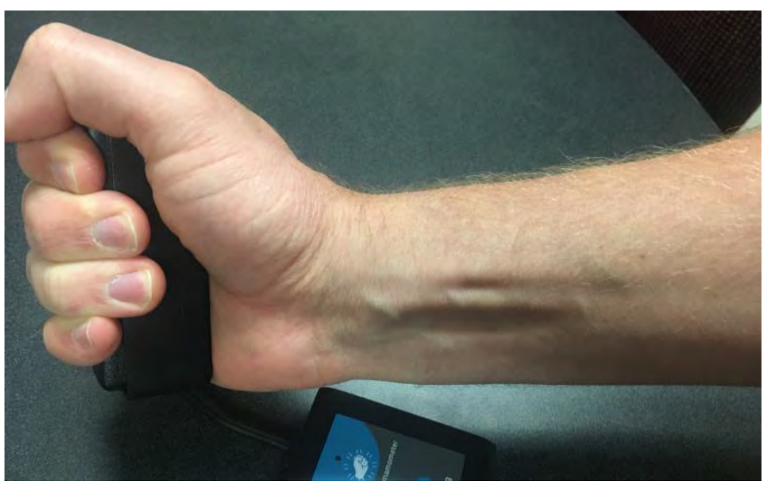

Figure 7: Handgrip task

The tracing puzzle task (Baumeister et al., 1998; Glass, Singer, & Friedman, 1969) was used as a mental performance persistency task. To solve the puzzle, the participants was given a completed geometric figure, a stack of notecards, and a pen. Participants were told to draw the geometric figure without lifting up their pen and without retracing any lines **(Figure 8)**. If the participant failed an attempt to complete the drawing, they were asked to lay the used notecard to the side and start on a new notecard. The participants were told to take as much time as they wanted and to make as many attempts as they wanted. Participants were told that they were not judged based on the time or number of attempts needed to complete the puzzle, only whether or not they completed it. Unbeknownst to the participant, the puzzle presented was impossible to complete without lifting the pen (A) (Ent, Baumeister, & Tice, 2015). Participants were scored based on number of attempts and time spent attempting the puzzle. Participants were allotted a maximum of fifteen minutes to attempt the puzzle. The researcher gave participants directions and an easy practice puzzle to complete during the training period (B).

A.

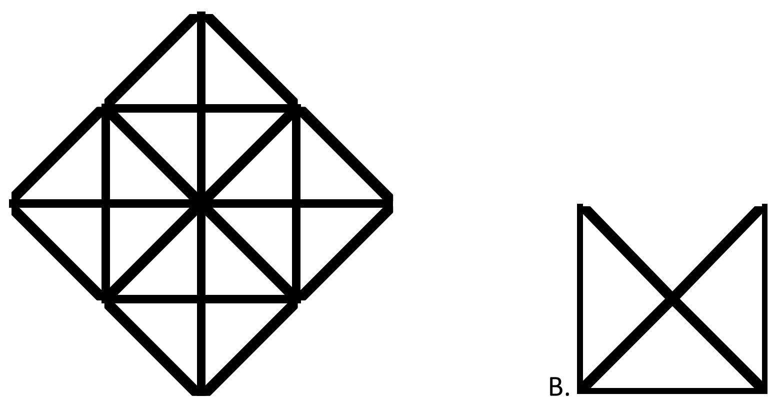

Figure 8: Tracing puzzle drawings: A) impossible test puzzle, B) practice puzzle.

The State Self-Control Capacity Scale (Christian & Ellis, 2011; Twenge et al., 2004) was used as a self-report state self-control assessment **(see Appendix G)**. The Self-Control Capacity Scale was developed to assess momentary differences in self-control and shows good internal consistency and retest reliability. The questionnaire presented a series of ten statements and asked participants to check the box that best represented them. Each statement referenced actions or thoughts (e.g., I feel like my willpower is gone), and had participants respond on a five-point Likert scale from *not at all like me* to *very much like me*.

The Monetary Choice Questionnaire (Kirby et al., 1999) was used as a delay of gratification task **(see Appendix H)**. The questionnaire presented a series of twenty-seven questions which asked whether participants would prefer a smaller money amount sooner or a larger money amount later (e.g., would you prefer $54 today, or $55 in 117 days). The amount of money for each option and the length of delay varied for each question. Participants were able to respond in one of two ways; smaller sooner (*smaller reward today*) or larger later (*larger reward in the specified number of days*). The participants were told to take the task literally, because they were given the opportunity to win one of the actual options they select at the end of the session.

Research Chair

The same cooling apparatus (i.e., research chair with cooling packs) used in Study 1 to induce cold stress was used in Study 2. In addition, an 18" box fan was used to blow 5-10 mph room temperature air across the participants to increase cold perception (Osczevski, 1995).

Physiological Monitoring

The same physiological monitoring devices and thermometers used in Study 1 to objectively measure stress were used in Study 2.

Additional Subjective Measures

Two subjective measures used in Study 1 - (Stanford Sleepiness Scale (SSS), and Thermal Comfort Assessment (TCA)) - were again administered using the same parameters as in Study 1. Two additional surveys were also be administered after the testing session - the Brief Self-Control Scale, and the Grit Scale. The Brief Self-Control Scale (BSCS) (Tangney et al., 2004) was developed as a trait scale to assess individual differences in self-control and shows good internal consistency and retest reliability **(see Appendix I)**. The BSCS questionnaire presented a series of thirteen statements and asked participants to choose the response that best represented them. Each statement referenced actions or thoughts (e.g., I'm good at resisting temptation), and had participants respond on a five-point Likert scale from *not at all like me* to *very much like me*.

The Grit Scale (Duckworth & Gross, 2014; Duckworth et al., 2007) was used to measure grit as a personality trait **(see Appendix J)**. The Grit Scale questionnaire presented participants with a series of twelve statements and asked participants to choose the response that most applied to them. Each statement referenced personal traits (e.g., I am a hard worker), and had participants respond on a five-point Likert scale from *not at all like me* to *very much like me*. When responding, participants were asked to think of how they compared to most people; not just the people they knew well, but most people in the world. Participants were also told that there was no right or wrong answers and to answer honestly.

Design

Study 2 used a between-subjects design with two conditions **(Table 2)**. One condition was a cold condition, in which the participants completed the tasks under cold stress. The other condition was a comfortable condition, in which the participants performed the tasks without cold stress and at a comfortable room temperature. Participants completed a five minute physiological vanilla baseline while comfortable, followed by a relaxation period in their given condition. Four experimental tasks were completed after the relaxation period, and the tracing task was always completed last; this was done for two reasons. First, sustained effort such as trying to solve a difficult puzzle over an extended period has been shown to deplete self-control (Inzlicht & Gutsell, 2007). As such, this longer task should not precede any other measure of momentary self-control. Secondly, because the length of time used to attempt the task could potentially have varied between one minute and fifteen minutes, the tracing task should always be completed last so it does not introduce excess cooling effects to a superseding tasks if the participant choose to make attempts for the full fifteen minutes. Participants were not told that the tracing puzzle task was the final task. The Brief Self-Control Scale and Grit Scale were always administered after the four experimental tasks (comfortable surveys) as opposed to before the tasks so the participant did not become self-aware of the studies purpose and alter their behavior. These measures were personality trait based measures and were not expected to vary with time or condition.

Table 2: Study 2 timeline

Cold Condition	Setup Baseline and Training	Cold Relaxation	Cold Tasks 1-3	Cold Tracing Task	Comfortable Surveys
Comfortable Condition	Setup Baseline and Training	Comfortable Relaxation	Comfortable Tasks 1-3	Comfortable Tracing Task	Comfortable Surveys
		5 min	15 min	5-15 min	10 min

Reliability Measures

Research staff members were fully trained in study procedure prior to participant testing. All study procedure and descriptions were written out prior to testing to ensure each participant received the same instruction **(see Appendix K)**. Two researchers monitored the participants throughout the session and recorded any problems that occurred for the purpose of data integrity **(see Appendix E)**.

Procedure

Individuals who were interested were scheduled for a 75 minute timeslot. Once they arrived, participants were given the chance to have questions answered before they signed the informed consent and began any procedures. Once signed, basic demographic information was taken which included general mental and physical health questions **(see Appendix F)**.

After the demographic survey was completed, the participants were shown an example of the handgrip task, tracing puzzle task, Monetary Choice Questionnaire, and were given an explanation of how to complete the tasks. This was considered the training period and allowed the participants to ask questions and become familiar with each task. After the training period was completed the physiological equipment was attached. The temperature thermocouple was connected to a portable data logger then attached to the back of the participant's non-dominant hand using breathable medical tape. An alcohol swab and skin prep gel were used to clean the fingers, then the skin conductance sensor and BVP sensor was snuggly fit on the pinky, middle, and index fingers. An alcohol swab and skin prep gel were again used to clean the area over the dorsal portion of the trapezius muscle, then the EMG sensor was attached between the shoulder and neck using as adhesive electrode pad. The respiration sensor was snuggly fit around the middle of the ribcage using a Velcro strap. Attaching all the sensors took approximately five minutes. After all the sensors had been attached, temperature was taken from the ear, sleepiness was assessed using the SSS, and thermal comfort was assessed using the TCA. Taking temperature, sleepiness scores, and thermal comfort scores took approximately one minute.

After the participants were set up, they were carefully seated in the research chair with special attention put towards not moving the sensors. During this point in the study there were no cooling packs placed on the chair. Once in the chair, the participants sat upright and quietly read an article for five minutes while the physiological equipment recorded a vanilla baseline (Fishel et al., 2007). After the baseline was recorded, temperature was taken from the ear, sleepiness was assessed using the SSS, and thermal comfort was assessed using the TCA. Participants were reminded that they could leave and discontinue the study at any time if they were overly uncomfortable.

After the baseline period was completed, the participants started their randomly assigned condition. If the participant was assigned to the cold condition, three ice packs were placed on the research chair to create a cold stressor. In addition, a box fan was placed in such a way that it blew room temperature air across the participants' lower body to bolster cold perception. If the participant was assigned to the comfortable condition, no ice packs were placed on the research chair, no fan was used, and the chair remained at room temperature. The angle of the chair back was slightly reclined backwards 30° and the participants were instructed to close their eyes and relax for five minutes. After the five minute relaxation period, temperature was taken from the ear, sleepiness was assessed using the SSS, and thermal comfort was assessed using the TCA. Up to this point in the study, the procedure had been identical to that used in Study 1, with the exceptional addition of the fan.

After the relaxation period was completed and while the participant was still seated, the participant performed three tasks (State Self-Control Capacity Scale, Monetary Choice Questionnaire, and handgrip task) in a randomized order. Once each task was completed, temperature was taken from the ear, sleepiness was assessed using the SSS, and thermal comfort was assessed using the TCA. After one task was completed the participants then performed the next task. This procedure was followed for each of the three tasks. After the last randomized task was completed, the participants completed the tracing puzzle task. Prior to this task, participants were again reminded that they could discontinue the study at any time if they were overly uncomfortable. The final task was always the tracing puzzle task and it was considered complete when the participant stated that they gave up on the task or fifteen minutes has elapsed. Once the final task was completed, temperature was again taken from the ear, sleepiness was assessed using the SSS, and thermal comfort was assessed using the TCA.

After the four tasks were completed, participants were given a five minute warm up period. For those participants in the Cold condition this involved the cold packs being removed from the chair and them sitting back in the chair without cold stress. For those participants in the comfortable condition this involved standing up briefly and sitting back down in the chair without cold stress to mimic the cold condition procedure. Participants were given additional time to warm up if needed and were asked to inform the researcher when they were comfortable based on the TCA if they had been uncomfortably cold after the five minutes. After participants in both conditions were comfortable, they completed two surveys (Grit Scale and

Brief Self-Control Scale) in a randomized order. Following the completion of the final survey the session was considered complete.

After the surveys were complete, the researcher used a random number generator to discover if the participant had won a crash award or not **(see Appendix L)**. If the participant won, the amount and the time the participant would receive the award depended on a randomly selected answer the participant choose during the Monetary Choice Questionnaire. If the participant had chosen to take the reward immediately they were given the amount they selected as they leave the laboratory, if the participant had chosen to delay for a period of time the participant was given a date on which they may return to receive the amount. The participant was dismissed after this point.

Data Analysis

Data was again organized and analyzed using Microsoft Excel spreadsheets and the IBM SPSS 22 statistical package. The independent variable being manipulated was also the participant's level of thermal stress. Cold stress was quantitatively measured using the same objective and subjective methods as in Study 1, and the dependent variable was the participant's performance on the separate self-control measures. A 2 (*condition*: cold, comfortable) X 4 (*measure*: perception, discomfort, arousal, ear temperature) mixed ANOVA with a Bonferroni corrected post hoc was used to assess variability in cold perception, thermal comfort, arousal, and core temperature between each task from the vanilla baseline. Change from baseline with confidence intervals are reported. A 2 (*condition*: cold, comfortable) X 5 (*task*: relaxation, handgrip, state SC, monetary choice, puzzle) mixed ANOVA with a Bonferroni corrected post hoc was used to assess variability in the physiological measures between each task from the vanilla baseline. Change from baseline with confidence intervals are reported. A 2 (*condition*: cold, comfortable) X 12 (*time*: 10 second intervals) mixed ANOVA was used to test for main effects and interactions in handgrip performance between groups. A 2 (*condition*: cold, comfortable) X 10 (*scale items*) MANOVA was used to compare overall score and component scores on the State Self-Control Capacity Scale. A 2 (*condition*: cold, comfortable) X 1 (state self-control summed composite score) X 1 (*control*: trait self-control) ANCOVA was used to compare overall score and component scores on the State Self-Control Capacity Scale while controlling for trait self-control. A 2 (*condition*: cold, comfortable) X 3 (*reward*: small, medium, large) MANOVA was used to compare monetary decisions on the Monetary Choice Questionnaire. And a 2 (*condition*: cold, comfortable) X 2 (*puzzle performance:* time to failure, number of attempts) MANOVA was used to compare performance on the tracing puzzle task.

Self-Control Measures

The performance measure of the handgrip task is the force the grip was held with for 120 seconds. An inability to sustain force over time was associated with lower self-control (E. Miles et al., 2016). The performance measure of the tracing puzzle task is the length of time and the number of attempts made to complete the puzzle before the participant gave up on the task. Again, an inability to sustain effort or make attempts was associated with lower self-control (Ent et al., 2015). The performance measure for the State Self-Control Capacity Scale is the participant's subjective sense of momentary self-control as indicated on a 7-point Likert scale. Self-identifying with low self-control statements in the moment was associated with lower self-control (Christian & Ellis, 2011).

The performance measure for the Monetary Choice Questionnaire was the individual's delay-discount rate when given monetary choices. Choosing to receive smaller monetary rewards sooner rather than later is associated with impulsivity and therefore lower self-control (Kirby et al., 1999). Scoring and deriving discount rates was calculated using the University of Kansas Monetary Choice Questionnaire Automated Scorers application (Kaplan, Lemley, Reed, & Jarmolowicz, 2014). Choices range between low (e.g., $34 today or $35 186 days), medium (e.g., $19 today or $25 53 days), and high (e.g., $20 today or $55 7 days) discounting decisions. High future discounting decisions are associated with an unwillingness to wait short amounts of time for larger gains in value, and are indexed with a *k-value* (Kirby & Maraković, 1996). *The k-value* is reached by solving for *k* in the equation $V = A/(1 + kD)$: where V = value today, A = future value, and D = wait in days (Gray, Amlung, Palmer, & MacKillop, 2016).

Subjective Control Variables

The performance measure for the Brief Self-Control Scale is the participant's subjective sense of trait self-control as indicated on a 5-point Likert scale. Self-identifying with low trait self-control statements is associated with having low self-control as a trait separate from any stress manipulation (Tangney et al., 2004). The performance measure for the Grit Scale is the participant's subjective sense of trait grit as indicated on a 5-point Likert scale. Self-identifying with low trait grit statements is associated with having low grit as a trait separate from any stress manipulation (Duckworth & Gross, 2014).

Temperature and Physiological Measures

Similar to Study 1, temperature and physiological measures were again compared between conditions and tasks.

Results

Study 1 (Results)

Participants

Participants assigned to the cold first condition did not vary from those in the comfortable first condition in any measurable way. Collapsing across groups, when participants arrived at the session they had an average ear temperature of 98.49°F (*SD*=.67), were not sleepy (SSS, *M*=2.08, *SD*=.72), their thermal perception was neutral (TCA, *M*=5.00, *SD*=.99), and they were thermally comfortable (TCA, *M*=1.98, *SD*=.74). Additionally, global sleep habit scores indicated that participants in the study were normal sleepers (PSQI, *M*=5.26, *SD*=2.15).

Cold Stress Manipulation

A 2 (*condition*: cold first, comfortable first) X 3 (*time*: baseline, Time 1, Time 2) mixed ANOVA was used to test for main effects and interactions. There was not a main effect of condition (*p*=.675), however there was a main effect of time ($F(2,98)=58.35$, $p<.001$, $\eta^2_p=.544$), and an interaction ($F(2,98)=84.96$, $p<.001$, $\eta^2_p=.634$) for cold perception, **(Table 3, Figure 9)**. There was not a main effect of condition (*p*=.258), however there was a main effect of time ($F(2,98)=48.83$, $p<.001$, $\eta^2_p=.499$), and an interaction ($F(2,98)=80.89$, $p<.001$, $\eta^2_p=.623$) for thermal comfort **(Table 3, Figure 10)**. There was not a main effect of condition (*p*=.348), however there was a main effect of time ($F(2,98)=24.66$, $p<.001$, $\eta^2_p=.335$), and an interaction

($F(2,98)=9.29$, $p=.001$, $\eta^2_p=.159$) for arousal as measured with the SSS **(Table 3, Figure 11)**. There was not a main effect of condition ($p=.267$), nor a main effect of time ($p=.873$), however there was an interaction ($F(2,48)=5.00$, $p=.011$, $\eta^2_p=.172$) for tympanic ear temperature **(Table 3, Figure 12)**. Continuous skin temperature across the session is shown in **Figure 13**.

Table 3: Table of thermal stress values

	Cold First Condition			Comfortable First Condition		
Task	*M* Diff (*SE*)	95% CI	*p*	*M* Diff (*SE*)	95% CI	*p*
Time 1						
Perception	-2.48 (0.24)	[-3.11, -1.84]	**<.001**	-0.19 (0.23)	[-0.79, 0.41]	1.000
Discomfort	-1.72 (0.22)	[-2.28, -1.15]	**<.001**	-0.03 (0.1)	[-0.3, 0.22]	1.000
Arousal	-0.28 (0.21)	[-0.82, 0.26]	.599	-0.23 (0.21)	[-0.78, 0.32]	.893
Ear Temp	-0.26 (0.14)	[-0.63, 0.09]	.211	0.18 (0.1)	[-0.08, 0.44]	.281
Time 2						
Perception	-0.08 (0.24)	[-0.7, 0.54]	1.000	-2.23 (0.23)	[-2.82, -1.63]	**<.001**
Discomfort	-0.2 (0.18)	[-0.66, 0.26]	.853	-1.57 (0.18)	[-2.05, -1.1]	**<.001**
Arousal	-1.36 (0.34)	[-2.23, -0.48]	**.002**	-0.23 (0.19)	[-0.73, 0.26]	.740
Ear Temp	-0.14 (0.16)	[-0.56, 0.27]	1.000	0.04 (0.09)	[-0.18, 0.28]	1.000

Note: Difference from baseline in repeated assessment of cold stress. A negative (-) change in mean difference (M Diff) represents an increase from baseline (Diff = Baseline - Value).

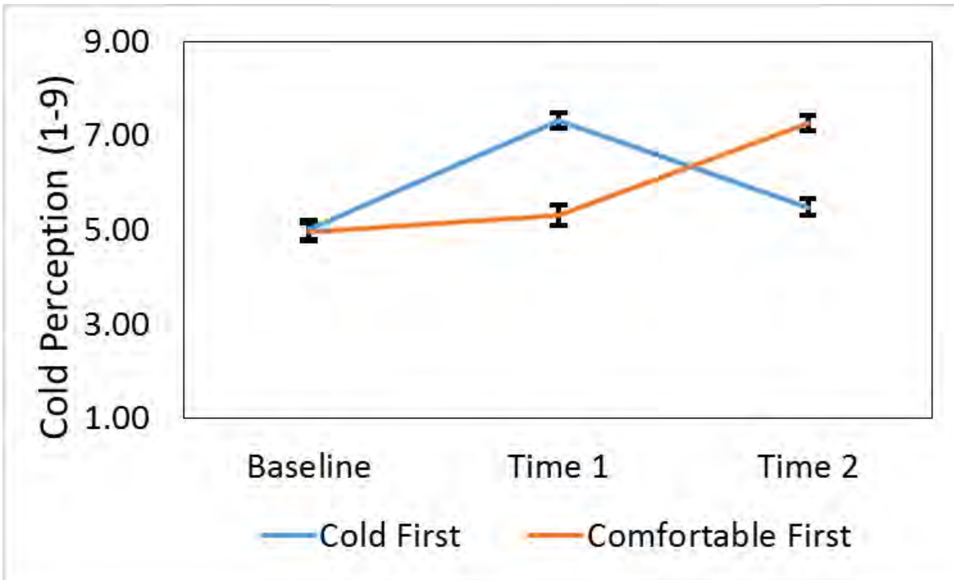

Figure 9: Cold perception between groups on the TCA (larger number = perceived more cold). A line graph is being used to present this data to make it easier to follow the groups as they switch conditions, and to represent task order across time.

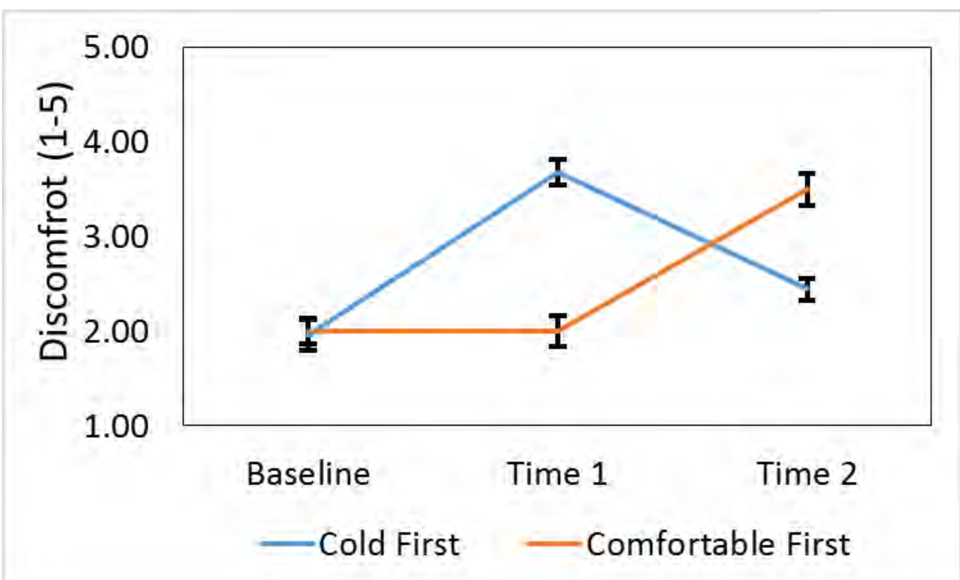

Figure 10: Thermal discomfort between groups on the TCA (larger number = more uncomfortable).

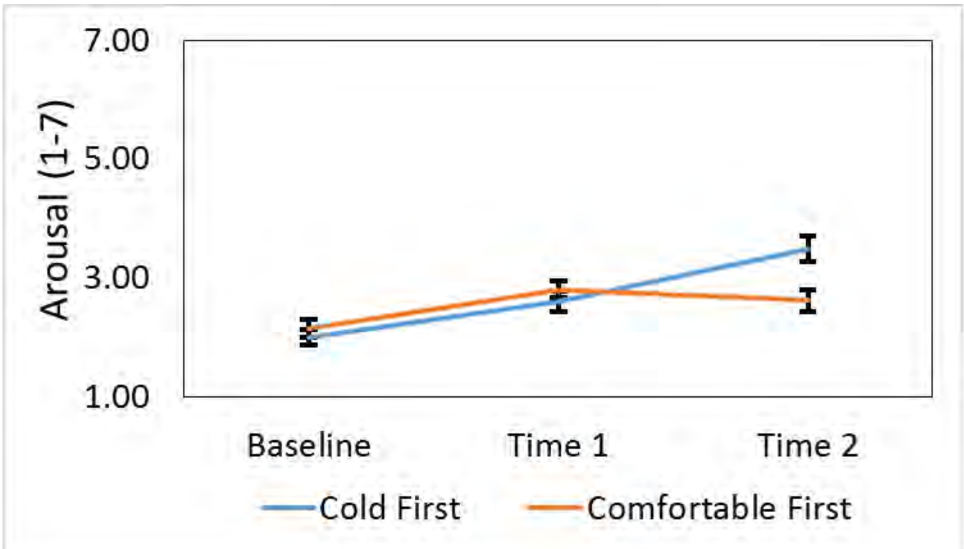

Figure 11: Arousal scores between groups on the SSS (lower values = higher arousal).

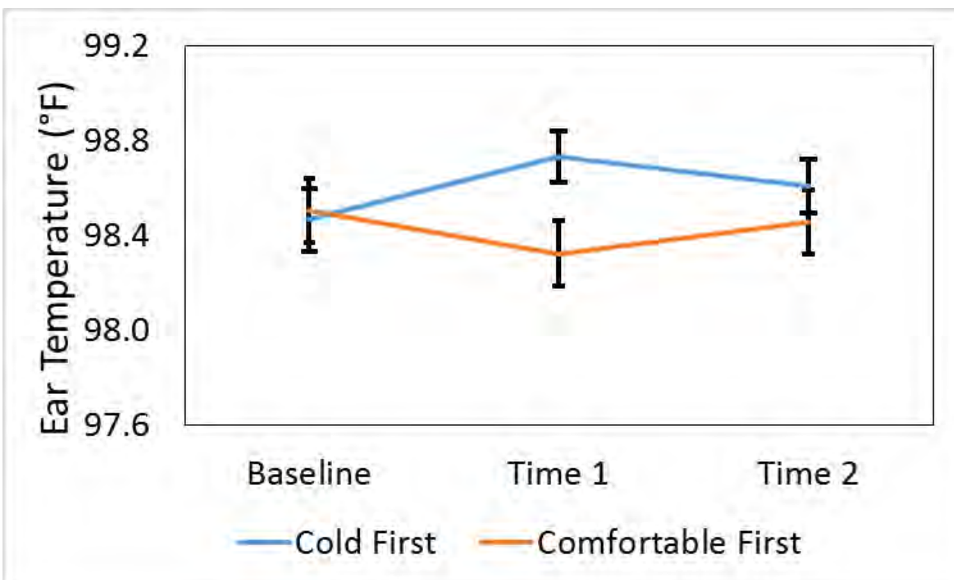

Figure 12: Ear temperature between groups.

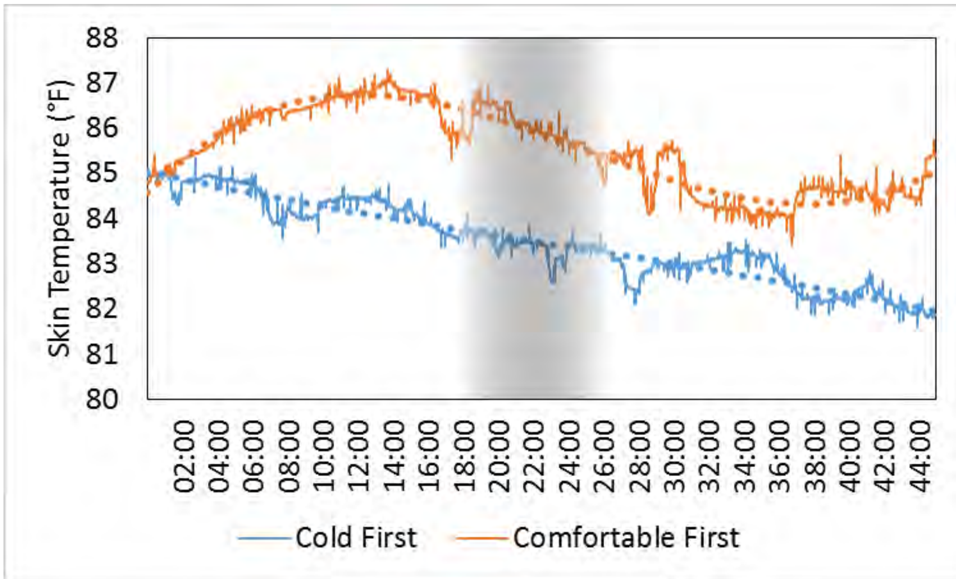

Figure 13: Hand skin temperature between groups. The gray area is a general estimate of when participants entered the adjustment period.

Physiological Measures

A 2 (*condition*: cold first, comfortable first) X 2 (*period*: relax, task) mixed ANOVA was used to test for main effects and interactions. There was not a main effect of condition (p=.770), however there was a main effect of period ($F(1,49)=76.30$, $p<.001$, $\eta^2_p=.609$), and an interaction ($F(1,49)=5.41$, $p=.024$, $\eta^2_p=.099$) for change from baseline in skin conductance during Time 1 **(Table 4, Figure 14)**. Similarly, there was not a main effect of condition (p=.318), however there was a main effect of period ($F(1,49)=27.05$, $p<.001$, $\eta^2_p=.356$), and an interaction ($F(1,49)=8.59$, $p=.005$ $\eta^2_p=.149$) for change from baseline in skin conductance during Time 2. There was not a main effect of condition (p=.106), however there was a main effect of period ($F(1,49)=8.65$, $p=.005$, $\eta^2_p=.150$), although there was not an interaction (p=.718) for change from baseline in respiration during Time 1 **(Table 4, Figure 15)**. Similarly, there was not a main effect of condition (*p*=.828), however there was a main effect of period ($F(1,49)=5.23$, $p=.027$, $\eta^2_p=.096$), although there was not an interaction (*p*=.395) for change from baseline in respiration during Time 2. There was not a main effect of condition (*p*=.600), however there was a main effect of period ($F(1,48)=20.75$, $p<.001$, $\eta^2_p=.302$), although there was not an interaction (*p*=.303) for change from baseline in muscle tonus during Time 1 **(Table 4, Figure 16)**. There was not a main effect of condition (*p*=.901), nor period *p*=.069), nor an interaction (*p*=.665) for change from baseline in muscle tonus during Time 2. Due to severe noise in the signal, heart rate variability data could not be used in the analysis.

Table 4: Table of physiological values

	Cold First Condition			Comfortable First Condition		
Task	*M* Diff (*SE*)	95% CI	*p*	*M* Diff (*SE*)	95% CI	*p*
Time 1 Relax						
SC	2.34 (0.26)	[1.65, 3.03]	**<.001**	2.91 (0.4)	[1.88, 3.94]	**<.001**
Respiration	22.62 (1.21)	[19.49, 25.76]	**<.001**	21.3 (1.53)	[17.36, 25.24]	**<.001**
EMG	16.11 (4.43)	[4.66, 27.56]	**.004**	12.01 (3.25)	[3.66, 20.36]	**.003**
Time 2 Relax						
SC	2.11 (0.3)	[1.33, 2.89]	**<.001**	1.62 (0.4)	[0.58, 2.65]	**.001**
Respiration	21.95 (1.22)	[18.81, 25.09]	**<.001**	21.3 (1.87)	[16.47, 26.12]	**<.001**
EMG	12.32 (6.04)	[-3.28, 27.93]	.159	10.66 (3.6)	[1.4, 19.92]	**.020**
Time 1 Task						
SC	1.35 (0.28)	[0.62, 2.07]	**<.001**	1.2 (0.32)	[0.37, 2.03]	**.003**
Respiration	22.31 (1.29)	[18.99, 25.64]	**<.001**	20.91 (1.58)	[16.85, 24.96]	**<.001**
EMG	5.36 (5.95)	[-10.07, 20.8]	1.000	5.63 (3.05)	[-2.19, 13.45]	.230
Time 2 Task						
SC	1.19 (0.41)	[0.12, 2.25]	**.025**	1.36 (0.42)	[0.27, 2.45]	**.011**
Respiration	21.6 (1.2)	[18.49, 24.71]	**<.001**	21.14 (1.92)	[16.21, 26.07]	**<.001**
EMG	4.18 (5.95)	[-11.25, 19.62]	1.000	6.02 (4.32)	[-5.06, 17.12]	.527

Note: Difference from baseline (zero) in continuous assessment of physiological stress response. A negative (-) change in mean difference (M Diff) represents an increase from baseline (Diff = Baseline - Value).

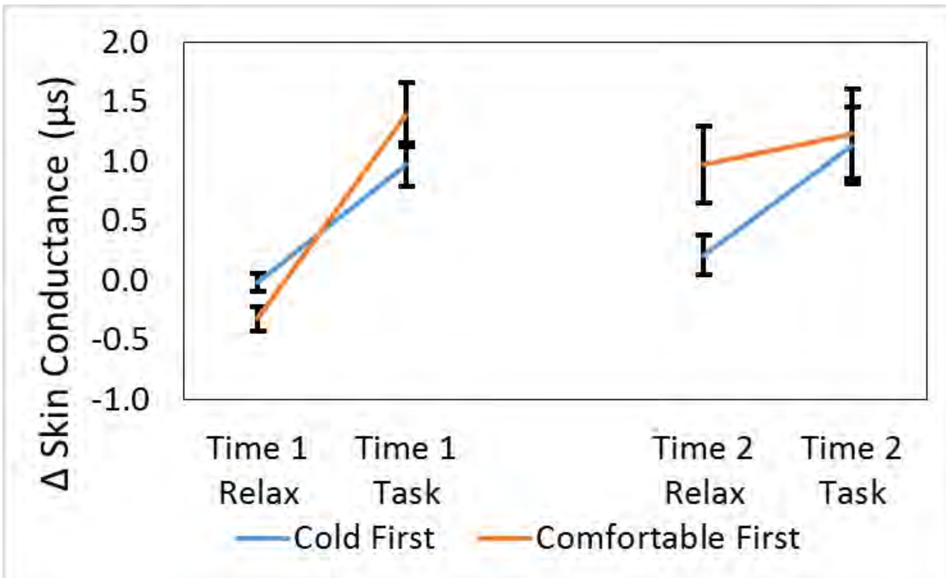

Figure 14: Change in skin conductance (microsiemens) from baseline between groups.

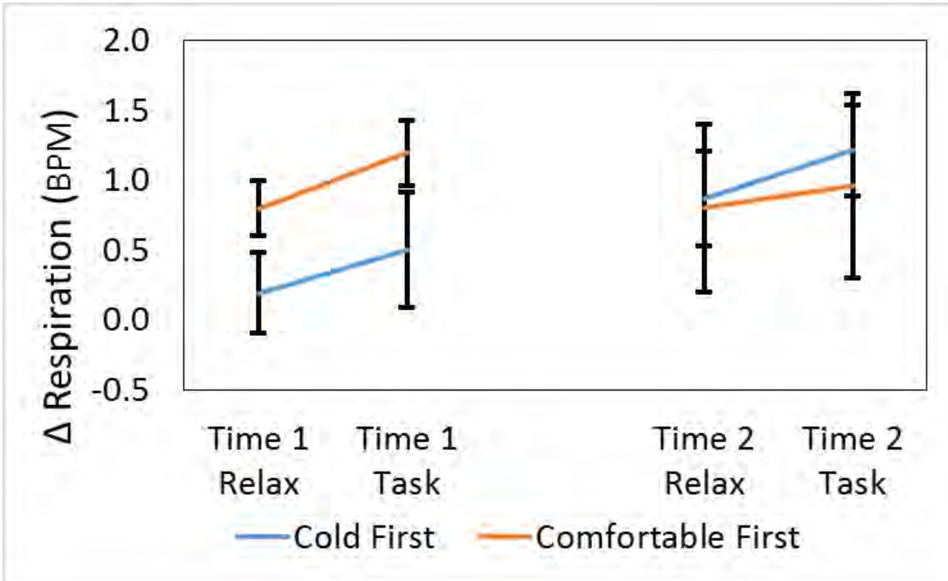

Figure 15: Change in respiration breaths per minute (BPM) from baseline between groups.

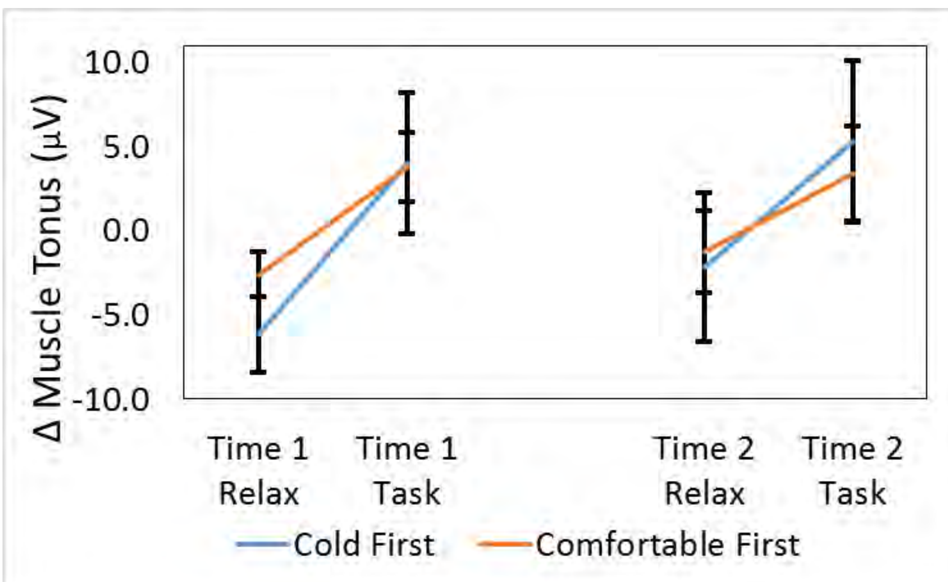

Figure 16: Change in muscle tonus activity (microvolts) from baseline between groups.

Cognitive Measures

A 2 (*condition*: cold first, comfortable first) X 2 (*time*: Time 1, Time 2) mixed ANOVA was used to test for main effects and interactions. There was not a main effect of condition (p=.257), however there was a main effect of time ($F(1,49)$=11.27, p=.002, η^2_p=.187), but there was not an interaction (p =.948) for number of false positives on the Arrow Flanker task **(Figure 17)**. There was not a main effect of condition (p=.936), however there was a main effect of time ($F(1,49)$=40.46, p<.001, η^2_p=.452), but there was not an interaction (p =.070) for overall response reaction time on the Arrow Flanker task **(Figure 18)**. There was not a main effect of condition (p=.156), nor time (p=.877), nor was there an interaction (p =.214) for overall errors on the Arrow Flanker task. There was not a main effect of condition (p=.983), nor time (p=.541), nor was there an interaction (p =.814) for number of false positives on the Stop-Signal task **(Figure 19)**. There was not a main effect of condition (p=.596), however there was a main effect of time ($F(1,49)$=7.18, p=.010, η^2_p=.128), but there was not an interaction (p =.596) for overall response reaction time on the Stop-Signal task **(Figure 20)**. Degree of physiological stress did not predict variability in reaction time or number of false positives in either task. Neither cold perception nor discomfort predicted variability in reaction time or number of false positives in either task. Neither ear nor skin temperature predicted variability in reaction time or number of false positives in either task.

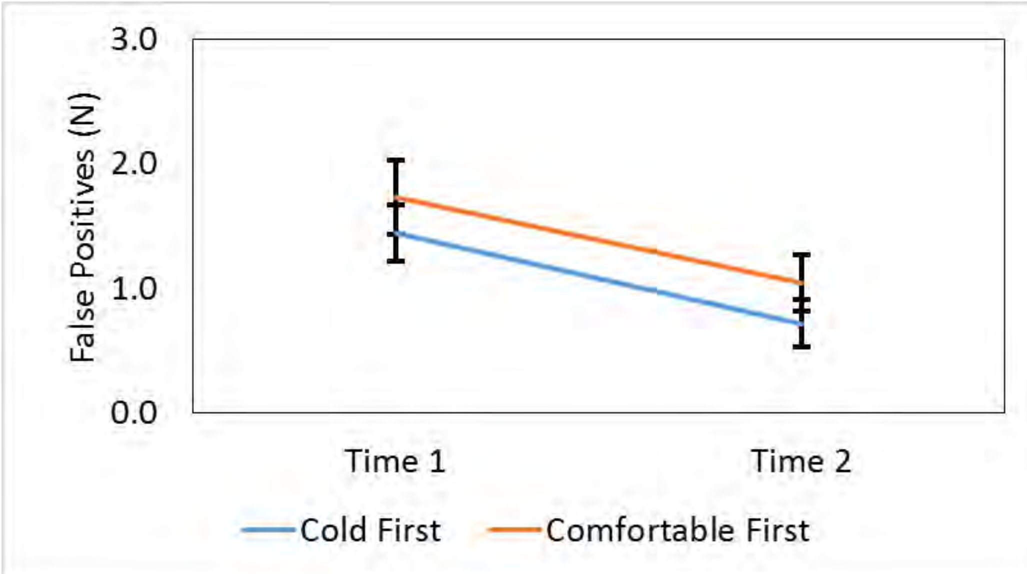

Figure 17: False positive responses between groups on the Arrow Flanker task (larger number = more errors).

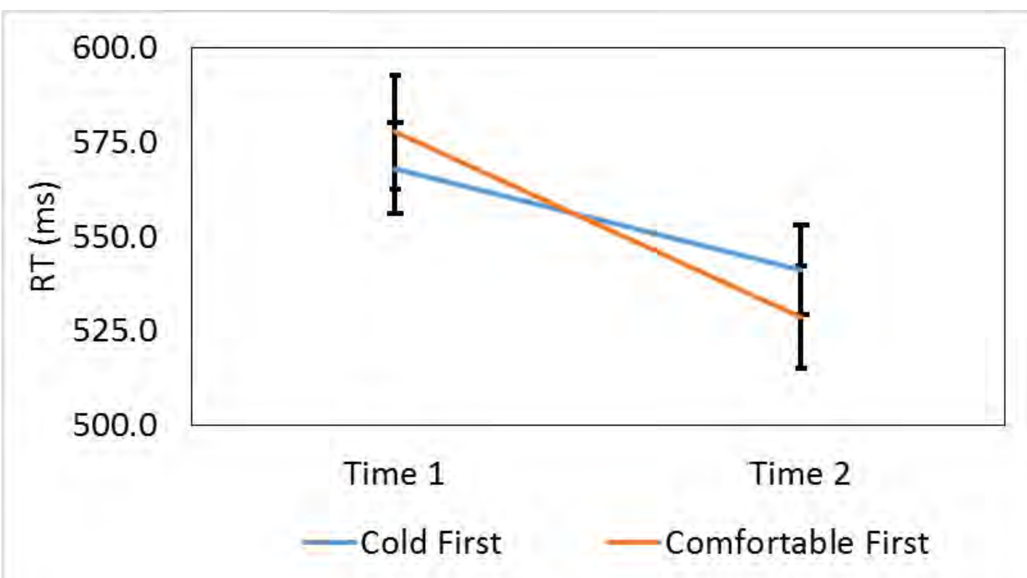

Figure 18: Reaction time of responses between groups on the Arrow Flanker task.

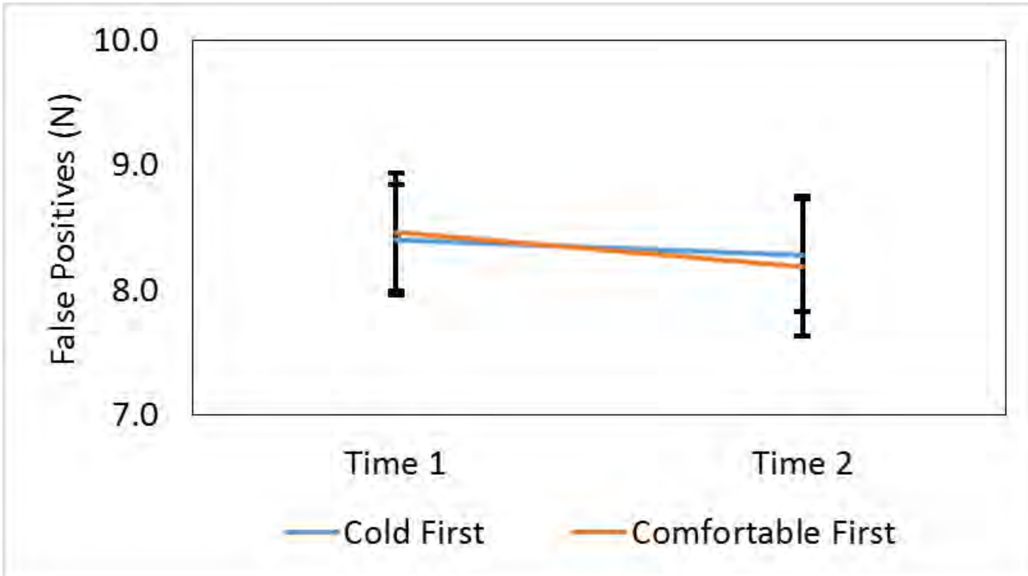

Figure 19: False positive responses between groups on Stop-Signal task (larger number = more errors).

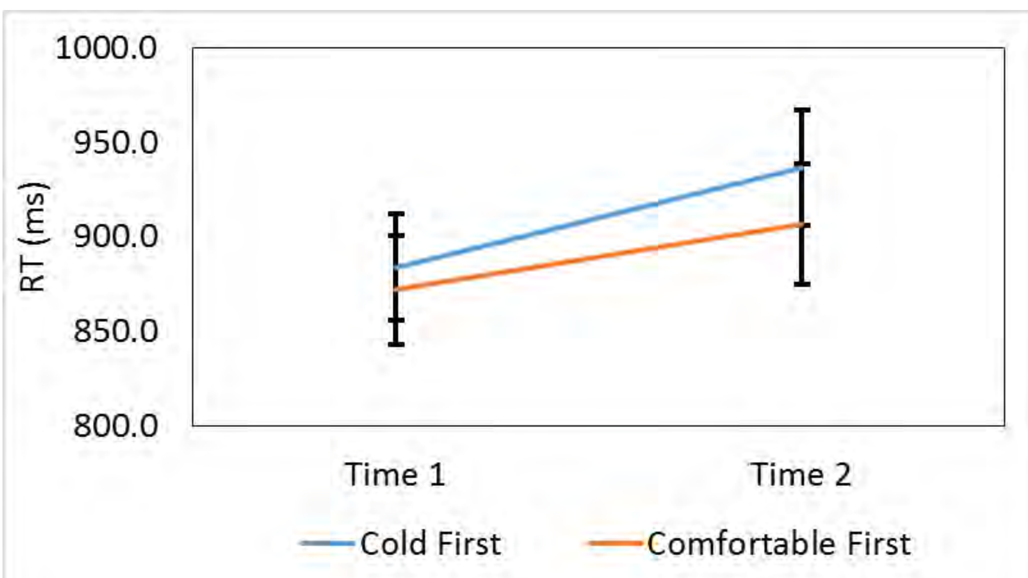

Figure 20: Reaction time of responses between groups on the Stop-Signal task.

Study 2 (Results)

Participants

Participants assigned to the cold condition did not vary significantly from those in the comfortable condition in any measurable way. Collapsing across groups, when participants arrived at the session they had an average ear temperature of 98.49°F (*SD*=.69), were not sleepy (SSS, *M*=2.69, *SD*=.93), their thermal perception was neutral (TCA, *M*=5.49, *SD*=.89), and they were thermally comfortable (TCA, *M*=2.27, *SD*=.70). Participants in the cold group did not show significantly more grit (*M*=3.46 *SD*=.60) than those in the comfortable group (*M*=3.40 *SD*=.50) using the Grit Scale (*p*=.625). Similarly, participants in the cold group did not show significantly more trait self-control (*M*=3.53 *SD*=.63) than those in the comfortable group (*M*=3.45 *SD*=.63) using the Brief Self-Control Scale (*p*=.588).

Cold Stress Manipulation

A 2 (*condition*: cold, comfortable) X 5 (*tasks*: relaxation, handgrip, state SC, monetary choice, puzzle task) mixed ANOVA with a Bonferroni corrected post hoc was used to test for perceptual and internal temperature differences between each task from the vanilla baseline. There was a main effect of condition ($F(1,74)=119.28$, $p<.001$, $\eta^2_p=.617$), a main effect of task ($F(4,71)=6.15$, $p<.001$, $\eta^2_p=.257$), however there was not an interaction ($p=.107$) for cold perception, **(Table 5, Figure 21)**. There was a main effect of condition ($F(1,74)=57.75$, $p<.001$, $\eta^2_p=.438$), however there was not a main effect of task ($p<.597$), nor an interaction ($p<.542$) for thermal comfort **(Table 5, Figure 22)**. There was not a main effect of condition (*p*=.188), however there was a main effect of task ($F(4,71)=13.26$, $p<.001$, $\eta^2_p=.428$), and an interaction ($F(4,71)=3.64$, $p=.009$, $\eta^2_p=.170$) for arousal **(Table 23, Figure 11)**. There was a main effect of condition ($F(1,74)=15.05$, $p<.001$, $\eta^2_p=.169$), a main effect of task ($F(4,71)=5.56$, $p<.001$, $\eta^2_p=.238$), and an interaction ($F(4,71)=2.72$, $p=.036$, $\eta^2_p=.133$) for tympanic ear temperature **(Table 24, Figure 12)**. Continuous skin temperature across the session is shown in **Figure 25**.

Table 5: Table of thermal stress values

	Cold Condition			Comfortable Condition		
Task	*M* Diff (*SE*)	95% CI	*p*	*M* Diff (*SE*)	95% CI	*p*
Relaxation						
Perception	-2.10 (.16)	[-2.62, -1.59]	**<.001**	-0.18 (0.1)	[-0.53, 0.15]	1.000
Discomfort	-1.48 (0.14)	[-1.94, -1.02]	**<.001**	0.05 (0.1)	[-0.28, 0.39]	1.000
Arousal	0.17 (0.16)	[-0.34, 0.7]	1.000	-0.64 (0.16)	[-1.15, -0.14]	**.004**
Ear Temp	0.74 (0.08)	[0.49, 1]	**<.001**	0.24 (0.06)	[0.04, 0.44]	**.007**
Handgrip						
Perception	-1.95 (.20)	[-2.57, -1.33]	**<.001**	0.48 (0.17)	[-0.06, 1.03]	.134
Discomfort	-1.43 (0.16)	[-1.96, -0.91]	**<.001**	-0.13 (0.11)	[-0.5, 0.23]	1.000
Arousal	0.56 (0.17)	[0.02, 1.1]	**.033**	0.4 (0.14)	[-0.04, 0.85]	.107
Ear Temp	1.05 (0.11)	[0.7, 1.39]	**<.001**	0.3 (0.08)	[0.03, 0.57]	**.015**
State SC						
Perception	-2.15 (.17)	[-2.68, -1.62]	**<.001**	-0.1 (0.14)	[-0.56, 0.34]	1.000
Discomfort	-1.51 (0.14)	[-1.95, -1.06]	**<.001**	-0.08 (0.11)	[-0.45, 0.29]	1.000
Arousal	0.41 (0.19)	[-0.19, 1.01]	.607	0.24 (0.15)	[-0.23, 0.72]	1.000
Ear Temp	0.99 (0.1)	[0.65, 1.33]	**<.001**	0.33 (0.07)	[0.1, 0.56]	**.001**
Monetary Choice						
Perception	-2.18 (0.15)	[-2.64, -1.72]	**<.001**	-0.05 (0.14)	[-0.52, 0.41]	1.000
Discomfort	-1.48 (0.14)	[-1.94, -1.02]	**<.001**	-0.21 (0.21)	[-0.88, 0.45]	1.000
Arousal	0.56 (0.2)	[-0.08, 1.21]	.146	0.1 (0.15)	[-0.37, 0.59]	1.000
Ear Temp	0.99 (0.1)	[0.65, 1.33]	**<.001**	0.34 (0.07)	[0.11, 0.58]	**.001**
Puzzle Task						
Perception	-2.05 (.20)	[-2.69, -1.41]	**<.001**	0.08 (0.21)	[-0.57, 0.74]	1.000
Discomfort	-1.48 (0.16)	[-2.01, -0.96]	**<.001**	-0.13 (0.11)	[-0.48, 0.21]	1.000
Arousal	0.74 (0.22)	[0.03, 1.45]	**.032**	0.29 (0.2)	[-0.33, 0.92]	1.000
Ear Temp	1.16 (0.09)	[0.86, 1.47]	**<.001**	0.32 (0.07)	[0.08, 0.55]	**.002**

Note: Difference from baseline in repeated assessment of cold stress. A negative (-) change in mean difference (M Diff) represents an increase from baseline (Diff = Baseline - Value).

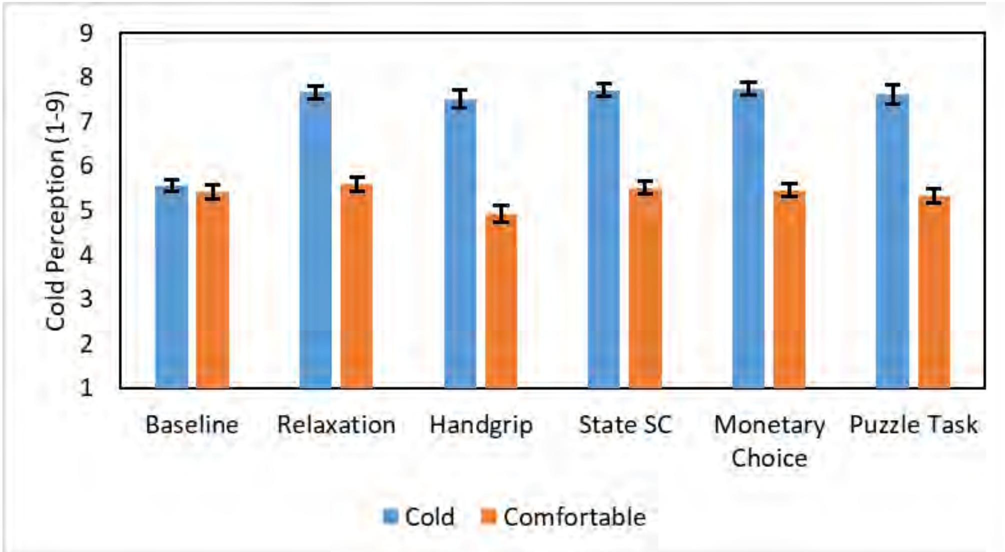

Figure 21: Cold perception between groups on the TCA (larger number = perceived more cold). A bar chart is being used to present this data because the conditions are random in order.

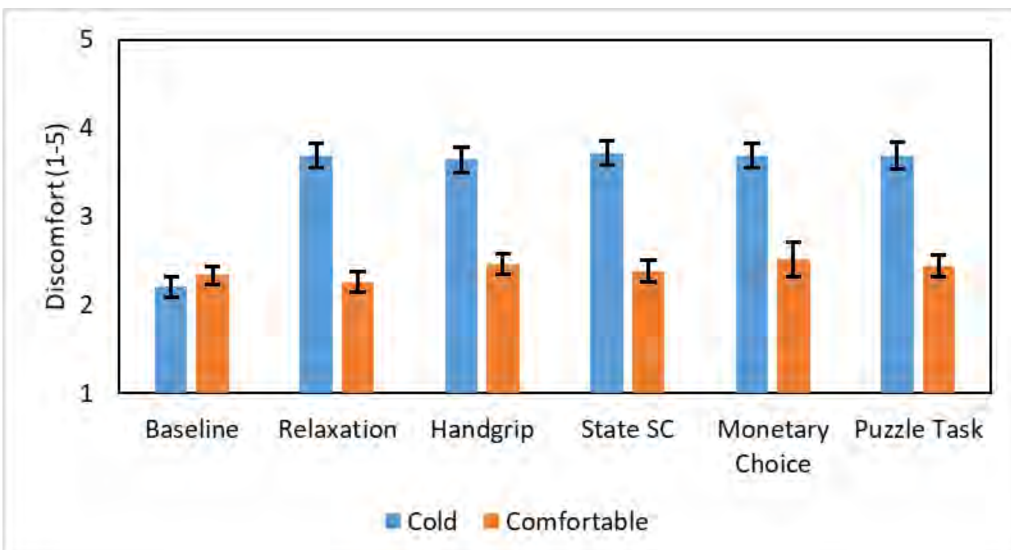

Figure 22: Thermal discomfort between groups on the TCA (larger number = more uncomfortable).

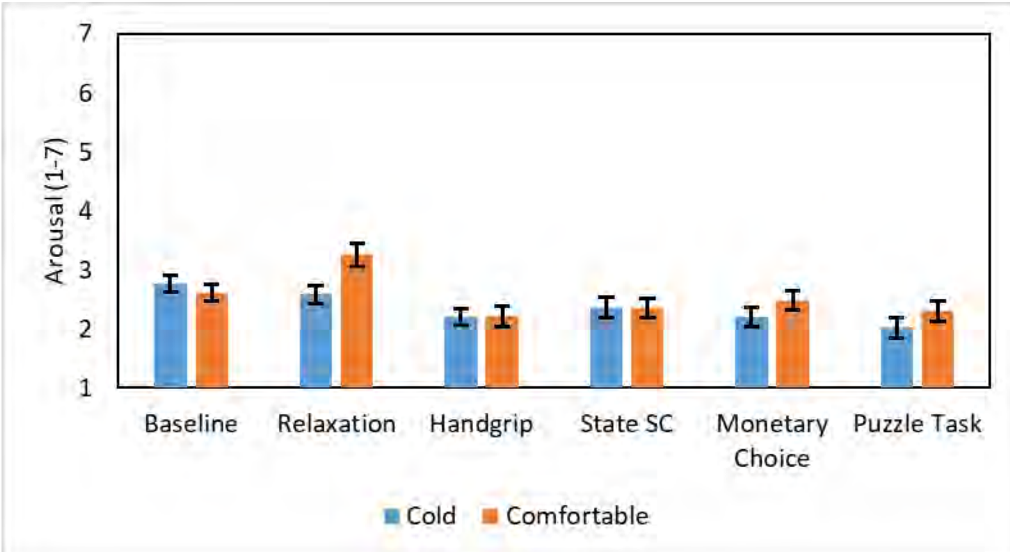

Figure 23: Arousal scores between groups on the SSS (larger number = more tired).

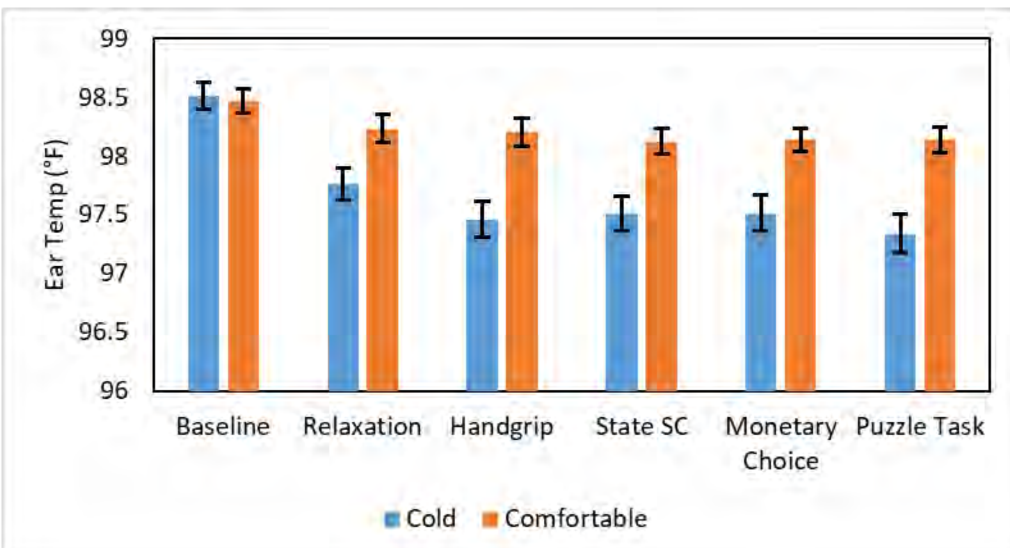

Figure 24: Internal temperature between groups.

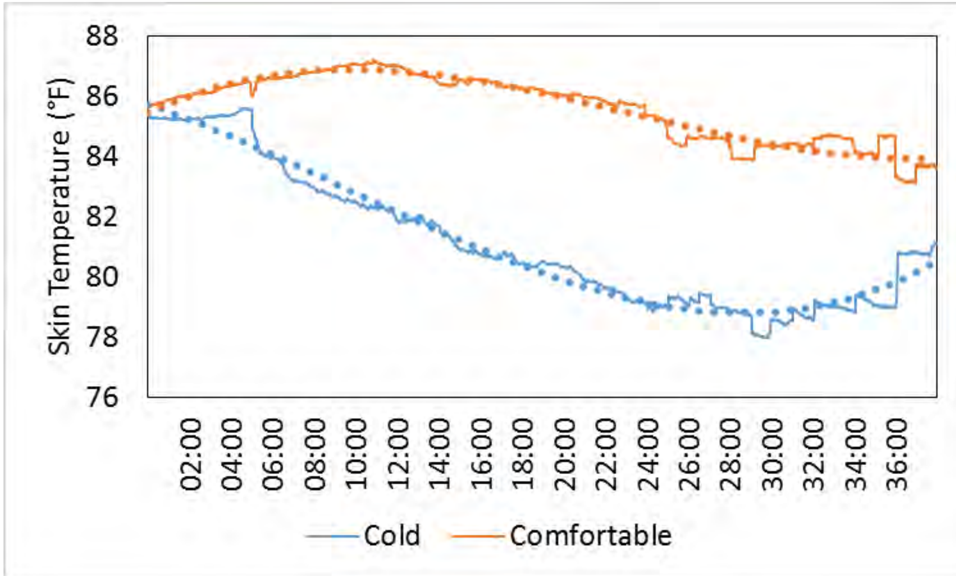

Figure 25: Hand skin temperature between groups over time.

Physiological Measures

A 2 (*condition*: cold, comfortable) X 5 (*task*: relaxation, handgrip, state SC, monetary choice, puzzle) mixed ANOVA with a Bonferroni corrected post hoc was used to test for physiological differences between conditions and each task from the vanilla baseline. There was not a main effect of condition (p=.407), however there was a main effect of task ($F(4,292)=45.59$, $p<.001$, $\eta^2_p=.384$), although there was not an interaction (p=.593) for change from baseline in skin conductance **(Table 6, Figure 26)**. There was not a main effect of condition (p=.998), however there was a main effect of task ($F(4,304)=7.90$, $p<.001$, $\eta^2_p=.094$), although there was not an interaction (p=.998) for change from baseline in respiration **(Table 6, Figure 27)**. There was not a main effect of condition (p=.940), however there was a main effect of task ($F(4,304)=18.95$, $p<.001$, $\eta^2_p=.200$), although there was not an interaction (p=.319) for change from baseline in muscle tone **(Table 6, Figure 28)**. Due to severe noise in the signal, heart rate variability data could not be used in the analysis.

Table 6: Table of physiological values

	Cold Condition			Comfortable Condition		
Task	*M* Diff (*SE*)	95% CI	*p*	*M* Diff (*SE*)	95% CI	*p*
Relaxation						
SC	-0.36 (0.16)	[-0.88, 0.16]	.540	-0.27 (0.07)	[-0.51, -0.03]	**.017**
Respiration	-0.3 (0.32)	[-1.32, 0.71]	1.000	-0.18 (0.91)	[-3.04, 2.67]	1.000
EMG	2.44 (1.25)	[-1.48, 6.38]	.879	3.55 (0.84)	[0.92, 6.19]	**.002**
Handgrip						
SC	-1.48 (0.23)	[-2.23, -0.73]	**<.001**	-1.38 (0.18)	[-1.96, -0.8]	**<.001**
Respiration	-1.36 (0.42)	[-2.69, -0.02]	**.042**	-1.31 (0.36)	[-2.46, -0.17]	**.014**
EMG	-7.33 (2.02)	[-13.66, -1.01]	**.012**	-10.69 (2.78)	[-19.43, -1.96]	**.007**
State SC						
SC	-1.44 (0.22)	[-2.15, -0.73]	**<.001**	-1.2 (0.17)	[-1.75, -0.64]	**<.001**
Respiration	-1.61 (0.44)	[-3.01, -0.21]	**.013**	-1.63 (0.3)	[-2.59, -0.66]	**<.001**
EMG	-6.49 (2.28)	[-13.63, 0.65]	.106	-7.03 (1.99)	[-13.29, -0.77]	**.017**
Monetary Choice						
SC	-1.34 (0.2)	[-1.99, -0.7]	**<.001**	-1.12 (0.16)	[-1.64, -0.6]	**<.001**
Respiration	-1.63 (0.43)	[-2.98, -0.28]	**.008**	-1.68 (0.35)	[-2.77, -0.58]	**<.001**
EMG	-8.41 (1.89)	[-14.36, -2.47]	**.001**	-10.45 (1.86)	[-16.29, -4.62]	**<.001**
Puzzle Task						
SC	-1.84 (0.28)	[-2.73, -0.94]	**<.001**	-1.44 (0.22)	[-2.13, -0.74]	**<.001**
Respiration	-1.83 (0.46)	[-3.3, -0.36]	**.005**	-1.92 (0.42)	[-3.27, -0.57]	**.001**
EMG	-13.4 (4.61)	[-27.84, 1.04]	.091	-10.45 (1.86)	[-16.29, -4.62]	**<.001**

Note: Difference from baseline (zero) in continuous assessment of physiological stress response. A negative (-) change in mean difference (M Diff) represents an increase from baseline (Diff = Baseline - Value).

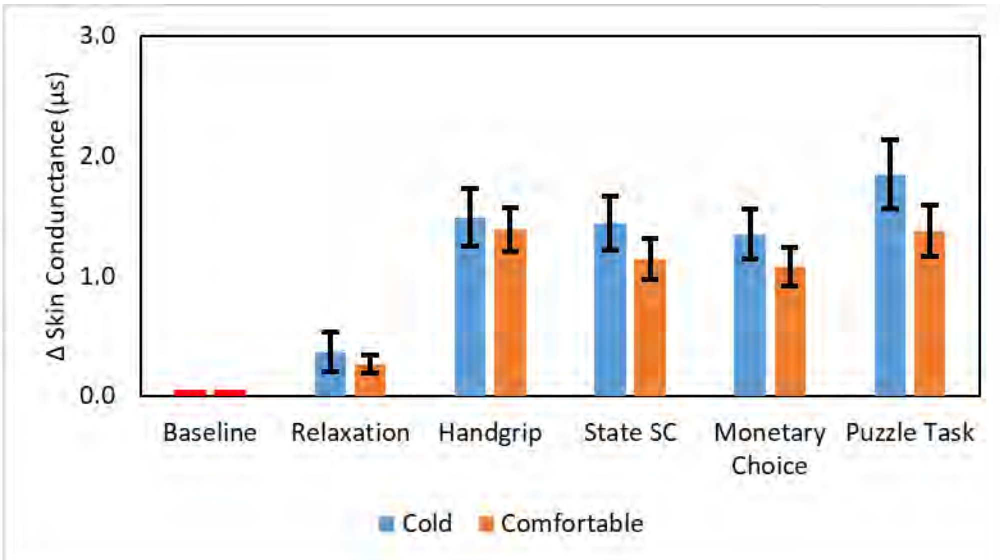

Figure 26: Change in skin conductance (microsiemens) from baseline between groups.

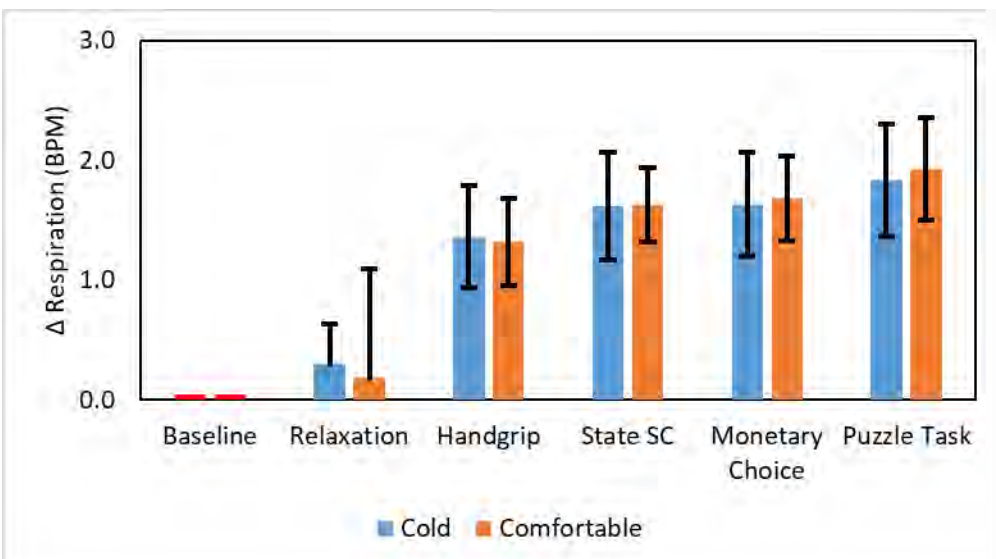

Figure 27: Change in respiration breaths per minute (BPM) from baseline between groups.

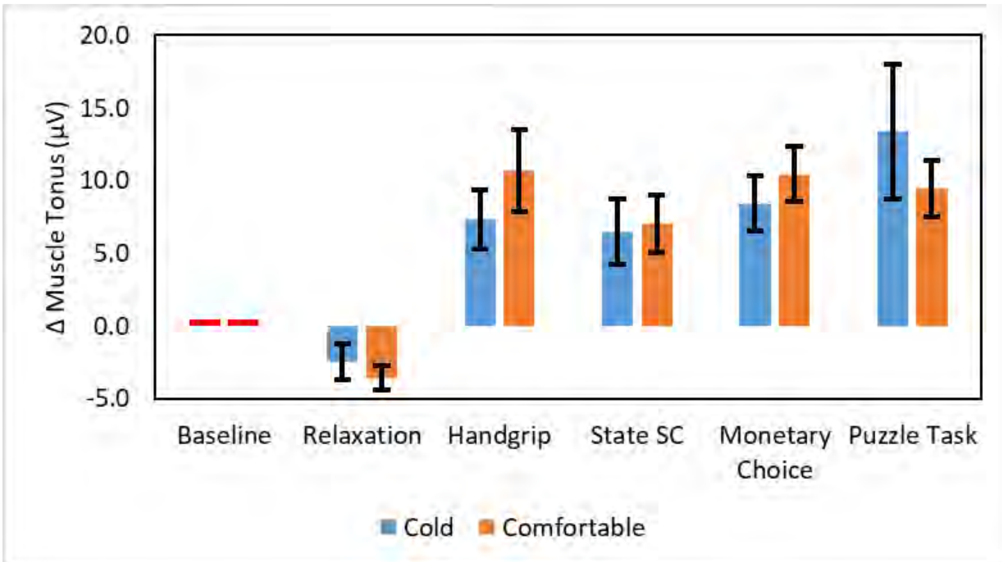

Figure 28: Change in muscle tonus activity (microvolts) from baseline between groups.

Self-Control Performance Measures

A 2 (*condition*: cold, comfortable) X 12 (*time*: 10 second intervals) mixed ANOVA was used to test for main effects and interactions in handgrip performance between groups. There was not a main effect of condition (p=.389), however there was a main effect of time (F(11,62)=21.85, p<.001, η^2_p=.795), although there was not an interaction (p=.783) for handgrip force **(Figure 29)**. Both conditions showed a similar decrease in force over time. Interestingly, ear temperature significantly correlated negatively with the amount of force still applied during the final ten seconds of the task r(74)=-.385, p=.001. An independent samples t-test was used to compare the percentage of max force applied during the final ten seconds of the task, however the two groups were again similar (p=.771). Degree of physiological stress did not predict variability in hand grip force over time. Neither cold perception nor discomfort predicted variability in hand grip force over time. Skin temperature did not predict variability in hand grip force over time.

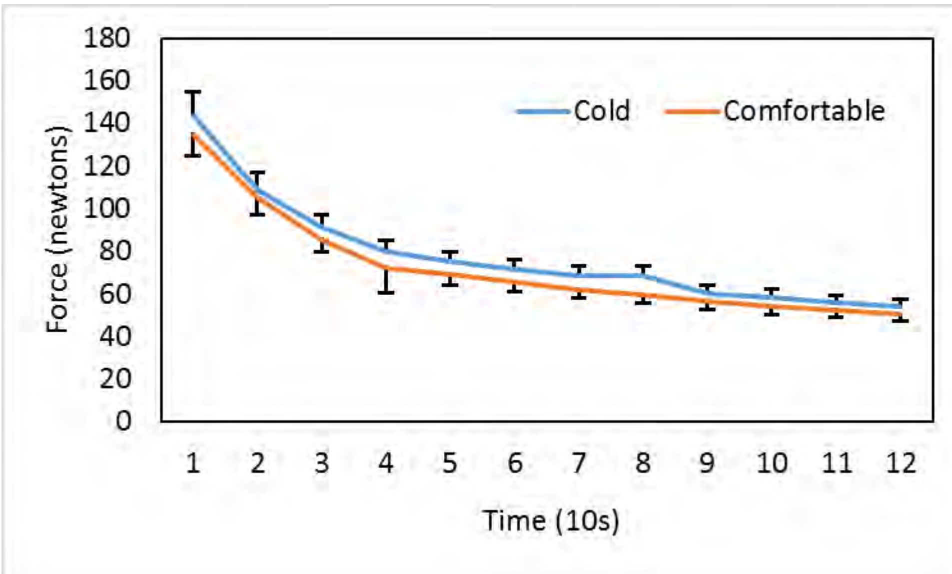

Figure 29: Amount of physical force applied to handgrip over time.

A 2 (*condition*: cold, comfortable) X 10 (*scale items*) MANOVA was used to compare overall score and component scores on the State Self-Control Capacity Scale **(Figure 30)**. Although the two groups were not different on their summed composite scores (p=.100), it is interesting to note that the resulting MANOVA of individual items was significant (F(10,67)=3.40, p=.001, η^2_p=.336). Participants in the cold condition rated Item 1: *I need something pleasant to make me feel better* (M=2.90, SD=.94; F(1,76)=9.88, p=.002, η^2_p=.115), and Item 3: *If I were tempted by something right now, it would be very difficult to resist* (M=2.26, SD=.97; F(1,76)=3.99, p=.049, η^2_p=.050) significantly more like them currently than the comfortable condition (M=2.18, SD=1.07; M=1.50, SD=.84 respectively). Additionally, they rated Item 5: *I feel calm and rational* (M=3.67, SD=.93; F(1,76)=17.77, p<.001, η^2_p=.190) significantly less like them currently than the comfortable condition (*M*=4.41, *SD*=.59). Item 1 and Item 5 were significantly correlated with cold perception ($r(78)=.277$, $p=.014$; $r(78)=-.422$, $p<.001$ respectively), and cold discomfort ($r(78)=.244$, $p=.032$; $r(78)=-.538$, $p<.001$ respectively).

The State Self-Control Capacity Scale summed composite score was significantly correlated positively with scores on the Grit Scale ($r(78)=.360$, $p=.001$) and the Brief Self-Control Scale ($r(78)=.706$, $p<.001$). A 2 (*condition*: cold, comfortable) X 1 (state self-control summed composite score) X 1 (*control*: trait self-control) ANCOVA showed a that those in the cold condition scored lower on state self-control (*M*=4.00, *SD*=.38) than those in the comfortable condition (*M*=4.15, *SD*=.42), when controlling for trait self-control ($F(2,74)=4.33$, $p=.041$, $\eta^2_p=.055$). Following a median split based on trait self-control, a 2 (*condition*: cold, comfortable) X 2 (*trait self-control*: high, low) ANOVA was used to test for differences between conditions and trait self-control. There was a main effect of condition ($F(1,74)=4.58$, $p=.036$, $\eta^2_p=.058$), a main effect of trait self-control ($F(1,74)=6.54$, $p=.013$, $\eta^2_p=.081$), although there was not an interaction ($p=.951$) for state self-control scores **(Figure 31)**. Degree of physiological stress did not predict variability in state self-control scores. Neither ear nor skin temperature predicted variability in state self-control scores.

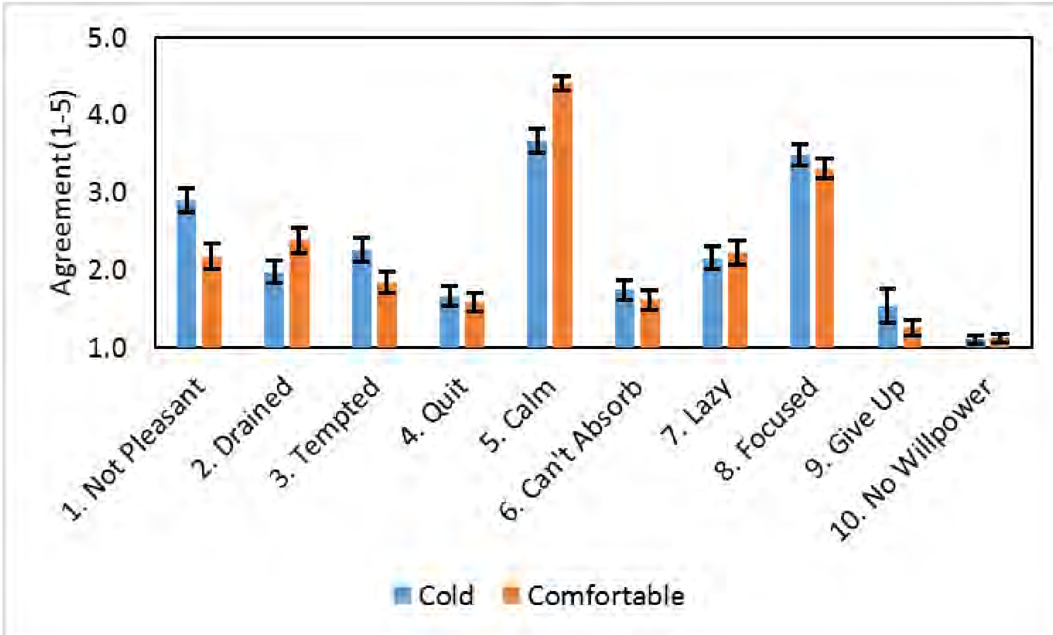

Figure 30: Scores on each item of the State Self-Control Capacity Scale.

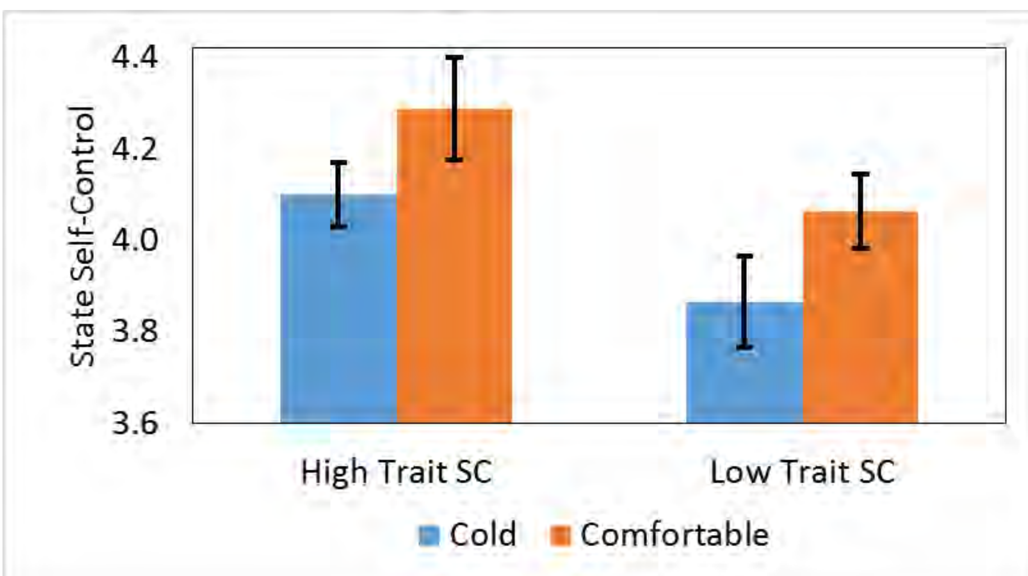

Figure 31: Self-control scores on the State Self-Control Capacity Scale by condition and trait self-control (higher values = higher self-control).

A 2 (*condition*: cold, comfortable) X 3 (*reward*: small, medium, large) MANOVA was used to compare monetary decision based on *k-value* for the Monetary Choice Questionnaire. The two groups did not differ in the percentage of small (p=.455), medium (p=.323), or large (p=.678) rewards they chose to delay gratification for **(Figure 32)**. The two groups did not differ in their future discounting *k*-value for small (p=.403), medium (p=.597), or large (p=.552) rewards **(Figure 33)**. However, higher *k*-value scores on small reward questions were significantly correlated negatively with poor handgrip performance $r(74)$=-.243, p=.042). Degree of physiological stress did not predict variability in reward selection. Neither cold perception nor discomfort predicted variability in reward selection. Neither ear nor skin temperature predicted variability in reward selection.

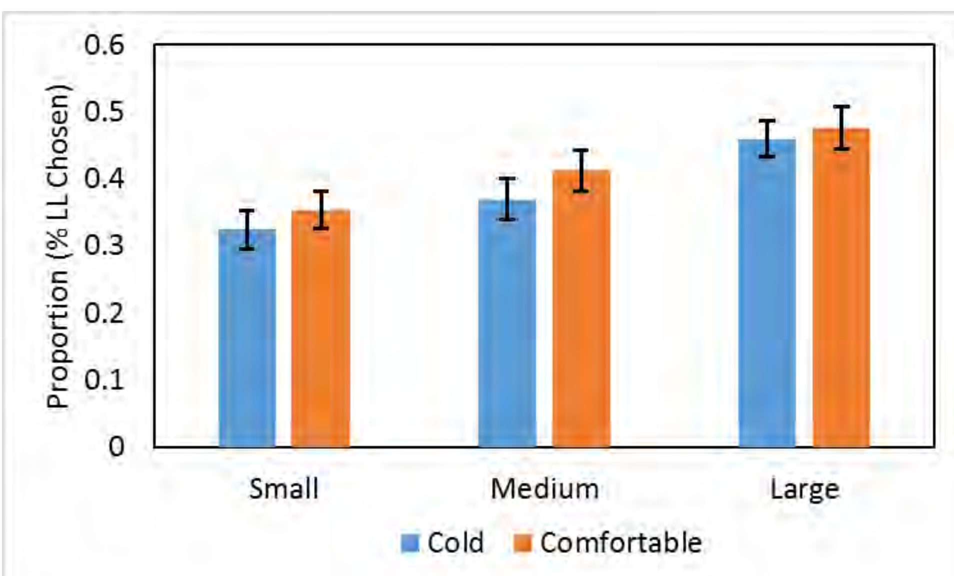

Figure 32: Proportion of rewards elected to wait for (i.e., chose the larger reward later) based on reward decision on the MCQ. Categories are defined by the size of the money value gain relative to the delay (e.g., small, $34 today or $35 in 186 days; medium, $19 today or $25 in 53 days; and high, $20 today or $55 in 7 days).

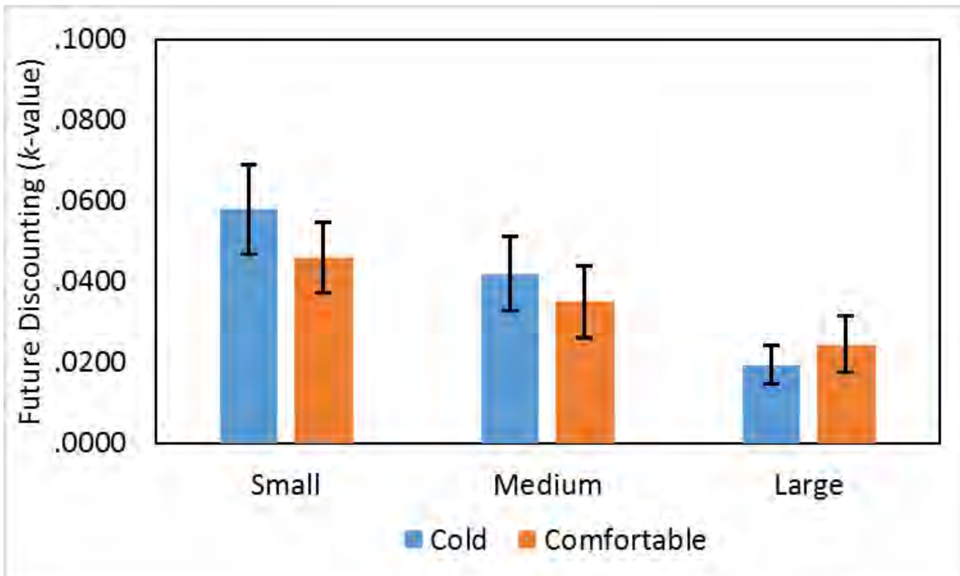

Figure 33: Future discounting (*k*-value) based on reward decision on the MCQ. Higher values = higher impulsivity.

A 2 (*condition*: cold, comfortable) X 2 (*puzzle performance:* time to failure, number of attempts) MANOVA was used to compare performance on the tracing puzzle task. The two groups did not differ in the time spent attempting to solve the impossible puzzle (*p*=.899), or the number of individual attempts at solving the impossible puzzle (*p*=.694) **(Figure 34)**. Degree of physiological stress did not predict variability in time or number of attempts. Neither cold perception nor discomfort predicted variability in time or number of attempts. Neither ear nor skin temperature predicted variability in time or number of attempts.

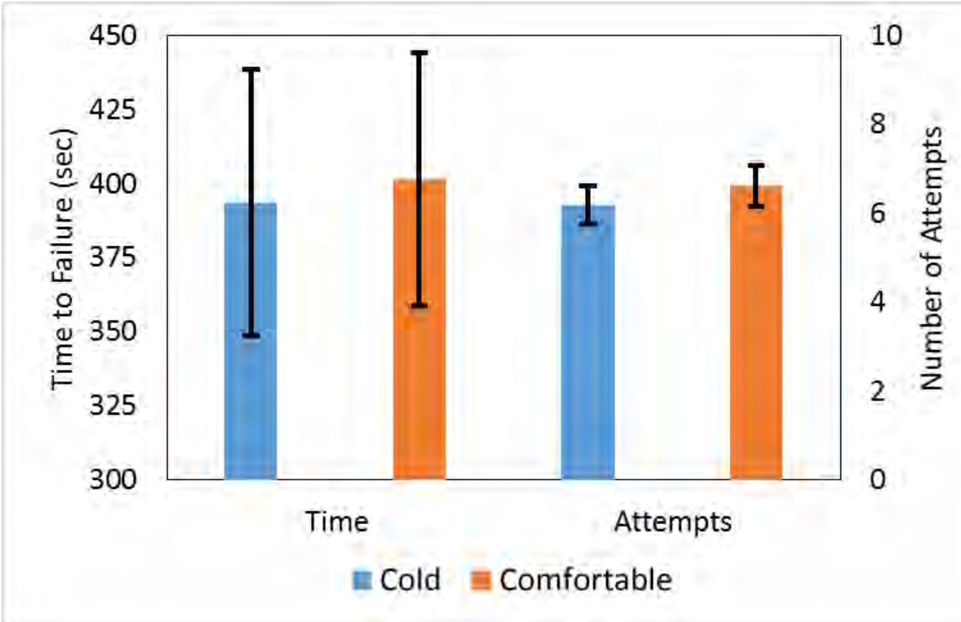

Figure 34: Time spent trying to solve the impossible puzzle and the number of attempts at solving the impossible puzzle by condition.

Discussion

The results from these two studies suggest that short term moderate levels of cold stress has a minimal impact on the use of momentary self-control. In this case, cold stress from skin cooling did not impact executive level inhibition, monetary decision making, or the ability to sustain effort physically or mentally. However, cold stress did impact individual momentary perception of self-control when controlling for trait self-control.

Hypotheses

Hypothesis 1, which predicted that cold stress would impact self-control, was partially supported. Hypothesis *1a* was not supported. Participants under cold stress did not show a greater number of false positive responses during the executive functioning tasks of Study 1

(Figures 17, 19). There was no main effect of condition and no evidence of interaction. There was a main effect of time for errors and reaction time, which suggests that participants did get better at the task with practice. With this consideration, it is possible that practice could have countered any detrimental effect due to cold exposure.

Hypothesis *1b* was supported. Participants under cold stress did score lower on the State Self-Control Capacity Scale of Study 2, which suggests a personal perception of limited self-control **(Figure 31)**. There was a main effect of condition when controlling for trait self-control as measured by the Brief Self-Control Scale. Cold stress had the strongest impact on self-reported feelings of temptation, mood, and reduced calm and rational feelings.

Hypothesis *1c* was not supported. Participants under cold stress did not show a greater preference for smaller rewards sooner over larger long term rewards during the delay of gratification task of Study 2 **(Figures 32, 33)**. This was consistent across rewards with small, medium, and large time-value disparities.

Hypothesis *1d* was not supported. Participants under cold stress did not to give up sooner on the two persistency tasks of Study 2 **(Figures 29, 34)**. There was no main effect of condition and no evidence of interaction for amount of continuous effort during the handgrip task of Study 2, nor the length of time or number of attempts used during the puzzle tracing task of Study 2.

Hypothesis 2, which predicted that measures of cold stress would be predictive of self-control, was partially supported. Hypothesis *2a* was partially supported. Cold perception and cold related discomfort did predict the degree of self-control decrement in specific instances.

Self-reported cold perception and cold related discomfort did significantly increase from a relaxed state in Study 1 in the cold condition, and a vanilla baseline in Study 2 in the cold condition **(Figures 9, 10, 21, 22; Tables 3, 5)**. Although it is interesting to note that increased levels of cold perception and discomfort were able to predict a reduction in pleasantness, and a reduction in calm and rational feelings; both of which are items from the State Self-Control Capacity Scale of Study 2 **(Figure 30)**. This was the only instance cold stress measures were predictive.

Hypothesis *2b* was partially supported. Skin temperature and internal temperature did predict the degree of self-control decrement in specific instances. Skin temperature from the back of the hand and internal temperature from the ear did significantly decrease from a baseline in both studies **(Figures 12, 13, 24, 25; Tables 3, 5)**. Increased ear temperature was able to predict a reduction in willful effort during the handgrip task of Study 2. However, this was the only instance it was predictive. Albeit, this instance had a negative correlation with effort, and may have indicated that participants with weak strength may instead have had a fever/illness.

Hypothesis *2c* was not supported. Muscle tone, skin conductance, and respiration did not predict the degree of self-control decrement in either study. However, muscle tone from the trapezius muscle, skin conductance from the hand, and thoracic respiration rate did significantly increase from a relaxed state in Study 1 and Study 2 **(Figures 14-16, 26-28; Tables 4, 6)**. This indicates the demanding nature of self-control tasks, although this variability was not predictive of individual self-control performance. Heart rate variability data could not be used in the analysis. Although photoplethysmography is an accurate method of measuring heart rate variability, it is very sensitive to small movements of the hand and fingers. Although participants were instructed not to move their non-dominant hand, they would tap their fingers or make a fist in such a way that the sensor would register the movement as an extra beat or an absence of a beat. This had a profound impact on the heart rate variability data.

General Discussion

Although the hypotheses of this study were not fully supported as expected, the findings raise an important question about the role of perception in self-control. The study condition reliably produced a cold-stress effect, as is supported by both subjective and objective measures of thermal stress. Participants in the cold condition reported feeling colder than the comfortable condition, and were uncomfortable with the condition. Likewise, their body demonstrated a traditional physiological cold stress response. Cold participants showed constricted peripheral blood vessels to reduce skin surface heat loss and pooled blood thoracically to preserve visceral core temperature. This responses is most commonly connected to those in outdoor occupations during the cooler months, but the body undergoes thermal regulation on a continuous basis, even for those in seemingly comfortable environments. Indeed, the feeling of being thermally comfortable is evidence of heterostatic thermal regulation as work.

In spite of this thermal stress, participants were able to equally maintain persistence on difficult tasks, resist cognitive response automaticity, and sacrifice short terms gains for long term rewards. This is likely due to two factors. First, it is presumed that because the body is so effective at protecting biological processes against thermal stress, the current cold stress was not intense enough to curtail performance because the threat from the stressor was relatively low. This aligns with Hancock's dynamic model of stress and sustained attention which emphasizes the ability of the body to physiological adapt to preserve cognitive performance (Hancock & Warm, 1989).

Second is the theoretical plausibility of limitless willpower. Inzlicht and colleagues have suggested that a failure in self-control in more akin to a switching of priorities based on motivation than an inability to perform (Inzlicht, Schmeichel, & Macrae, 2014). According to this theory, if the participants felt motivated to perform well on the task, and the thermal stressor was not strong enough to force them to reprioritize their wellbeing over task performance, task performance would not differ from the comfortable condition.

Indeed, participants in a laboratory setting are given an expectation to focus on the present task and try their best, and in fact cold participants did perform as well on the tasks as their comfortable counterparts. This observation is in agreement with *motivational goal-setting theory*, which states that specific and difficult tasks motivate high performance, and in turn increase effort and persistence (Locke & Latham, 2002). With regards to self-control failure, it can be theorized that self-control on a task would fail when individuals are no longer motivated to expose themselves to a high enough level of thermal discomfort (e.g., elect to complete a menial task for 1 hour while comfortable or elect to stop doing a menial task for 1 hour while very cold) (Muraven & Slessareva, 2003). In this case, the reward does not match the required amount of effort, and self-control could fail at relatively low levels of discomfort due to low motivation; a behavior based on *motivational equity theory* (Arvanitis & Hantzi, 2016).

As evidence, participants were given financial motivation to carefully weigh their decisions during the monetary choice task. During the cognitive tasks in Study 1, participants demonstrated enough motivation to perform as to demonstrate a practice effect from Time 1 to

Time 2. And physiological measures showed that participants were so motivated to perform well on the tasks that they demonstrated sympathetic reactivity; otherwise called flight-or-flight. Increased respiration, skin conductance, and muscle tonus was present during the self-control tasks, indicating a psychophysiological stress response separate from thermal stress, and evidence for a motivated effort (May, Sanchez-Gonzalez, Seibert, Samaan, & Fincham, 2016).

Even though participants in the cold condition were motivated and able to perform at a level equal to the comfortable condition on self-control tasks, they were given no feedback regarding their performance. As a result, cold participants predicted that they would be less able to perform well on self-control tasks. This result suggests that our perception of our own regulatory ability varies from our actual ability to self-regulate. In a series of visual perception experiments by Bhalla and Proffitt, the authors discovered that the perceived difficulty of physically climbing a hill increased if the individual was fatigued or encumbered by physical weight; a phenomena they called *visual-motor recalibration* (Bhalla & Proffitt, 1999). The author's explanation for this is a survival principal referred to as the economy of action, similar to the equity theory, this principal states that effort should be equally rewarded. Importantly though, individuals are imperfect at predicting the required effort of an action, and exertion seems more effortful when under stress (Proffitt, 2006). In particular, perceived effort seems to be more accurate in extreme cases. According to Proffitt, individuals are good at predicting when situations require very little effort, or a great amount of effort, but seem biased when situations require moderate effort.

The results of the current dissertation seem to extend this phenomena to self-control; a form of *self-control recalibration* **(Figures 35 and 36)**. As presented, thermal stress seems to alter perception of self-control by adding additional discomfort and stress to the interpretation. Indeed, it has been shown that distance perception from a high location is moderated by feeling of discomfort associated with that height, such as fear of falling (Stefanucci, Proffitt, & Clore, 2005). In the current research, instead of asking the question "how much do I not want to fall in my current state," they may be asking "how much do I not want to persist with a difficult task in my current state." This recalibration in subjective self-control occurs in those with high and low trait self-control. Interestingly, all forms of stress and fatigue do not affect perception of personal ability the same. During sleep deprivation, stressed individuals are generally overconfident in their abilities, and do not recognized the decrement sleep deprivation has on personal performance (Morris, Pilcher, Mulvihill, & Vander Wood, 2017). The current results show the opposite effect for self-control during cold stress.

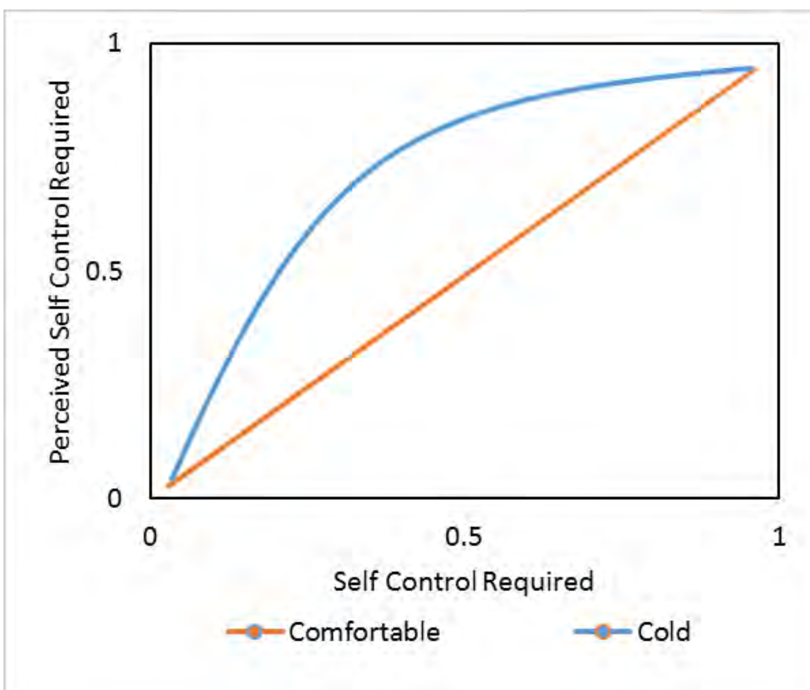

Figure 35: Theoretical perception of self-control analogous to the economy of action outlined in Proffitt (2006) *Embodied Perception and the Economy of Action*. Accurate perception is represented by a 1:1 ratio, and cold stress seems to skew that ratio to make self-control requirements seems higher.

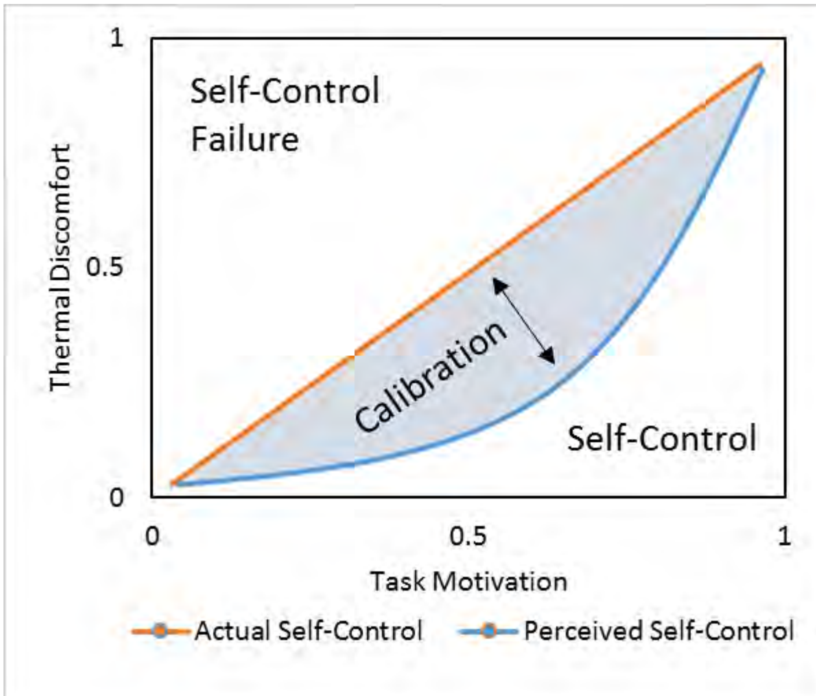

Figure 36: The possible disparity in the idealized point of actual self-control failure and perceived point of self-control failure. Self-control fails when there is no motivation or an intolerable level of discomfort. As motivation to perform the task increases, more discomfort is required to cause an individual to give up (self-control failure). Self-control is perceived to be excessively weakened under moderate levels of thermal stress, such as those present here.

In application, a theory of self-control recalibration could have two interpretations. One interpretation pulls from positive psychology literature and emphasizes that humans are capable of more than they think they are (Gable & Haidt, 2005). Although stressed participants did not believe they were able to resist temptation, they overcame the discomfort and chose to persist on with the task at hand. A second interpretation pulls from motivational psychology literature and emphasizes the role of endogenous factors in task performance, particularly an unwillingness to start using self-control under certain conditions (Grant & Shin, 2011). According to the aforementioned motivational equity theory, action is made when a reward matches perceived effort, or in the present context, an assumed willingness to maintain effort is performed when reward justifies discomfort. When participants were exposed to thermal discomfort, their personal interpretation of the task may have been that they are not willing maintain the same level of self-control in the future without additional motivation or incentive (S. R. Miles, Cromer, & Narayan, 2015). Indeed, cold participants reported that they needed something pleasant to make them feel better, a reference to increased incentive. Because they were not being provided any additional incentive for their discomfort, they reported a lower willingness to engage in self-control. In practice, someone in a comfortable state may be more willing to commit to a diet in the future, while someone uncomfortable may perceive that sticking to a future diet is more effortful and requires more self-control. Indeed, there exist relationships between comfortable seasonal temperatures and healthy behaviors that may be partially explained using this theory (Tucker & Gilliland, 2007).

Self-Control Debate

It is necessary to acknowledge that the psychological models of self-control are in a state of flux. Principally, the debate relates to whether self-control is resource based and whether a limited resource is a valid metric for manipulating and quantifying self-control. The strength-based model introduced by Muraven & Baumeister (2000) compares self-regulation to a muscle and suggests that a state of exhausted self-control resources (i.e., ego-depletion) can occur following the exercise of self-regulation (Baumeister et al., 2007). During this exhausted state, the ability to use self-control is limited and can lead to behavioral impulsivity until resources are replenished. These findings were evidence for a resource-based model of self-control, and have motivated the search for the specific resource in question. Blood glucose has been proposed as a biochemical fuel resource for self-control, but its role is considered negligible by some researchers (Hagger et al., 2010; Vadillo et al., 2016). Prior research also points to a psychological model of resource depletion as an explanation for limited self-control. Self-control requires cognitive effort and therefore a mental cost at the expense of cognitive processing (Hockey, 1997). Using this theory, sustained use of self-control leads to a form of motivational depletion, resulting in an unintentional shift in attention and motivation away from long-term goals. Following this shift, goal achievement can become difficult due to temptation, which results in more instances of failed self-control (Stroebe, Van Koningsbruggen, Papies, & Aarts, 2013). In this case, temptation to remove themselves from the uncomfortable cold condition.

Several studies have argued that any resource model of self-control ought to be abandoned (Kurzban, Duckworth, Kable, & Myers, 2013). Tice and colleagues (2007) have shown that individuals with depleted self-control can do equally as well as individuals with intact self-control if they are simply given a surprise gift; evidence that depletion may be irrelevant. Research has also shown that personal beliefs about the availability of willpower seems to mediate the availability of self-control, suggesting that much of self-control may simply reflect motivation (Job et al., 2010). By this account, correctly managed motivation may allow individuals to exercise self-control to a limitless degree (Inzlicht et al., 2014). However, despite the theoretical potential for limitless self-control, perfect self-control is not generally observed in the real world. Rather, an individual's inability to regulate behavior still leads to meaningful decrements in performance and a need for a practical index of that self-control. Instead of considering self-control a function of either resource or motivation, an integrated model which relies on both may be most practical (Pilcher et al., 2015).

Limitations and Future Research

The current studies have limitations that should be addressed. One limitation is the sample population, majority female young college students are not necessarily a representative group for the study. Research has suggested that age and gender is a moderating variable in both self-control and thermoregulatory response, and may limit generalizability in the findings (Parsons, 2002; Tittle, Ward, & Grasmick, 2003). Future research should include a population with a broader age range. Another limitation is specific to Study 1, and highlights the weakness of a crossover design for cold stress research. As can be seen in **Figure 13**, although participants in the cold first condition reported feeling thermally comfortable before starting the Time 2 tasks, skin temperature was still lower than those in the comfortable first condition during Time 1. As a result, there is evidence of lingering cold stress during their comfortable tasks that was not present during the comfortable first condition's comfortable tasks. Future research should use body temperature to determine if a participant has recovered from a thermal stress condition, or elect to use a between group design as was the case in Study 2.

In addition, the results of the study may be strongly dependent on the duration, amplitude, type, and direction of thermal stress. The current study only explored moderate cold exposure at the skin for less than an hour, which was intended to be applicable to outdoor work and occupations. As such, a great variety of exposures were not explored. The proposed model suggests that conditions of greater thermal stress for longer durations should result in actual self-control decrement. Albeit, this was not demonstrated here. Future research should explore a wider variety of cooling conditions.

Since this is some of the first evidence to suggest a form of self-control recalibration occurs during thermal stress, future research should continue to parse apart the observed effect theorized in Figure 36. It is entirely unclear whether the effect applies specifically to cold stress, or whether the effect also exists for heat stress, or indeed other sources of discomfort. Additionally it is theorized that the severity of the stressor would contribute to the degree of recalibration. Future research should explore less-cold conditions and more-cold conditions to observe if self-control ability is proportionately perceived according to the level of stress. Future research could also use tasks that participants are less motivated to complete. If motivation is truly the determining factor in persistence and self-control failure, self-control ability should fall as the discomfort rises and motivation to continue the task remains low.

Conclusion

Stress and our response to stress is ubiquitous to human life. Psychological stressors and biological stressors stemming from anxiety and physiological needs limit performance. However, these categories of stress are personal in nature and their influence is highly dependent on individual differences. By comparison, environmental stressors like thermal stress are global in nature, and have a wide ranging effect on human behavior. Self-control is an important component of human behavior. Although hundreds of articles have been published that argue the theories and principals that govern failure of self-control, very few have explored the effect of thermal stress (Carter, Kofler, Forster, & McCullough, 2015). The current series of studies provide evidence that moderate cold stress, such as that commonly exposed to in daily life, does not limit self-control. This hypothesis was supported in the context of persistence, delay of gratification, and cognitive definitions of self-control. However, cold stress does seem to influence how we view our own self-control limitations. Using the motivation model of self-control, the theory of self-control recalibration proposes that thermal stress may prevent us from attempting difficult tasks if we are predicting future outcomes by the likelihood of self-control failure. Previous research has shown that feelings of discomfort and fatigue influence our perception of danger and effort, and by the same mechanisms, thermal stress seems to make self-control failure appear more likely (Bhalla & Proffitt, 1999; Stefanucci et al., 2005). Following previous research, perception of self-control ability should match actual self-control in extreme cases (e.g., there is very high or very low motivation and discomfort), but will differ in most circumstances (Proffitt, 2006). In this way, recalibration is a valuable concept previous self-control research is yet to explore. Our ability to self-regulate is important, but so is our ability to predict our own performance.

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Appendices

[A]

Stanford Sleepiness Scale (SSS)

An Introspective Measure of Sleepiness

To be administered after each driving task

How I feel… (**circle one**)

1 Feeling active, vital, alert, or wide awake

2 Functioning at high levels, but not at peak; able to concentrate

3 Awake, but relaxed; responsive but not fully alert

4 Somewhat foggy, let down

5 Foggy; losing interest in remaining awake; slowed down

6 Sleepy, woozy, fighting sleep; prefer to lie down

7 No longer fighting sleep, sleep onset soon; having dream-like thoughts

How exhausting was that last task for you?

[B]

Pittsburgh Sleep Quality Index (PSQI)

1. During the past month, what time have you usually gone to bed at night?
2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?
3. During the past month, what time have you usually gotten up in the morning?
4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)
5. During the past month, how often have you had trouble sleeping because you . . .
    a. Cannot get to sleep within 30 minutes
    b. Wake up in the middle of the night or early morning
    c. Have to get up to use the bathroom
    d. Cannot breathe comfortably
    e. Cough or snore loudly
    f. Feel too cold
    g. Feel too hot
    h. Had bad dreams
    i. Have pain
    j. Other reason(s), please describe

6. During the past month, how would you rate your sleep quality overall?
7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?
8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?
9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?
10. Do you have a bed partner or room mate?
11. If you have a room mate or bed partner, ask him/her how often in the past month you have had . . .
    a. Loud snoring
    b. Long pauses between breaths while asleep
    c. Legs twitching or jerking while you sleep
    d. Episodes of disorientation or confusion during sleep
    e. Other restlessness while you sleep; please describe

[C]

Thermal Comfort Assessment (TCA)

An Introspective Measure of Thermal Comfort – Based on ISO 10551

How I feel… (**circle one**)

1 Very Hot

2 Hot

3 Warm

4 Slightly Warm

5 Neutral

6 Slightly Cool

7 Cool

8 Cold

9 Very Cold

How I feel… (**circle one**)

1 Very Comfortable

2 Comfortable

3 Neutral

4 Uncomfortable

5 Very Uncomfortable

[D]

Study 1 Script

Stanford Sleepiness Scale (SSS)

Using the following descriptions how do you feel right now?

Thermal Comfort Assessment (TCA)

Using the following descriptions how do you feel right now?

Pittsburgh Sleep Quality Index (PSQI)

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

Arrow Flankers task

For this task you will be using a tablet. Five figures will appear on the screen and the middle figure will be an arrow. Pay attention to the direction the middle arrow is pointing and press the soft-button beneath the figures corresponding to the direction it's pointing. If 'X's appear to the sides of the middle arrow, don't press anything and wait for the next set of figures to appear. You may begin when you are ready.

Stop-Signal task

For this task you will be using a tablet. The tablet will flash either an 'X' or an 'O'. If you see an 'X' you will push the left soft-button beneath the letter, and if you see an 'O' you will push the right button beneath the letter. If either letter appears with a line through it, don't press anything and wait for the next letter to appear. You may begin when you are ready.

[E]

Error Reporting Sheet

Participant Number: Date: Researcher:

Event

Condition: Neutral [ ] Cold [ ]

Task:

Description of Issue:

Participant Number: Date: Researcher:

Event

Condition: Neutral [ ] Cold [ ]

Task:

Description of Issue:

Participant Number: Date: Researcher:

Event

Condition: Neutral [ ] Cold [ ]

Task:

Description of Issue:

[F]

Demographics

Name:_______________________ DoB:___/___/___ Sex: M[ ] F[ ]

Participant number:_____________ Email:___________________________

Student year at Clemson University: Fr.[ ] So.[ ] Jr.[ ] Sr. [ ] Grad.[ ]

General health

1. How would you rate your overall general health?
   Excellent [ ] Good [ ] Average [ ] Fair [ ] Poor [ ]

2. How would you rate your overall mental health?
   Excellent [ ] Good [ ] Average [ ] Fair [ ] Poor [ ]

3. Do you take any medications regularly: Y[ ] N[ ]

   If yes, What medication:_____________

4. Do you possess any mental or physical health issues that could affect mental performance or reaction time: Y [ ] N [ ]

   Is yes, please explain: ____

[G]

State Self-Control Capacity Scale

Question	Not at all like me	A little like me	Some-what like me	Mostly like me	Very much like me
	1	2	3	4	5
1. I need something pleasant to make me feel better.*					
2. I feel drained.*					
3. If I were tempted by something right now, it would be very difficult to resist.*					
4. I would want to quit any difficult task I was given.*					
5. I feel calm and rational.					
6. I can't absorb any information.*					
7. I feel lazy.*					
8. I feel sharp and focused.					
9. I want to give up.*					
10. I feel like my willpower is gone.*					

[H]

Monetary Choice Questionnaire

For each of the next 27 choices, please indicate which reward you would prefer: the smaller reward today, or the larger reward in the specified number of days.

1. Would you prefer $54 today, or $55 in 117 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

2. Would you prefer $55 today, or $75 in 61 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

3. Would you prefer $19 today, or $25 in 53 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

4. Would you prefer $31 today, or $85 in 7 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

5. Would you prefer $14 today, or $25 in 19 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

6. Would you prefer $47 today, or $50 in 160 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

7. Would you prefer $15 today, or $35 in 13 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

8. Would you prefer $25 today, or $60 in 14 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

9. Would you prefer $78 today, or $80 in 162 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

10. Would you prefer $40 today, or $55 in 62 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

11. Would you prefer $11 today, or $30 in 7 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

12. Would you prefer $67 today, or $75 in 119 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

13. Would you prefer $34 today, or $35 in 186 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

14. Would you prefer $27 today, or $50 in 21 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

15. Would you prefer $69 today, or $85 in 91 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

16. Would you prefer $49 today, or $60 in 89 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

17. Would you prefer $80 today, or $85 in 157 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

18. Would you prefer $24 today, or $35 in 29 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

19. Would you prefer $33 today, or $80 in 14 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

20. Would you prefer $28 today, or $30 in 179 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

21. Would you prefer $34 today, or $50 in 30 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

22. Would you prefer $25 today, or $30 in 80 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

23. Would you prefer $41 today, or $75 in 20 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

24. Would you prefer $54 today, or $60 in 111 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

25. Would you prefer $54 today, or $80 in 30 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

26. Would you prefer $22 today, or $25 in 136 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

27. Would you prefer $20 today, or $55 in 7 days?

[ ] smaller reward today
[ ] larger reward in the specified number of days

[I]

Brief Self-Control Scale (BSCS)

Question	Not at all like me	A little like me	Some-what like me	Mostly like me	Very much like me
	1	2	3	4	5
1. I am good at resisting temptation					
2. I have a hard time breaking bad habits*					
3. I am lazy*					
4. I say inappropriate things*					
5. I do certain things that are bad for me, if they are fun*					
6. I refuse things that are bad for me					
7. I wish I had more self-discipline*					
8. People would say that I have iron self-discipline					
9. Pleasure and fun sometimes keep me from getting work done*					
10. I have trouble concentrating*					
11. I am able to work effectively toward long-term goals					

12. Sometimes I can’t stop myself from doing something, even if I know it is wrong*					
13. I often act without thinking through all the alternatives*					

[J]

Grit Scale

Question	Not at all like me	A little like me	Some-what like me	Mostly like me	Very much like me
	1	2	3	4	5
1. I have overcome setbacks to conquer an important challenge.					
2. New ideas and projects sometimes distract me from previous ones.*					
3. My interests change from year to year.*					
4. Setbacks don't discourage me.					
5. I have been obsessed with a certain idea or project for a short time but later lost interest.*					
6. I am a hard worker.					
7. I often set a goal but later choose to pursue a different one.*					
8. I have difficulty maintaining my focus on projects that take more than a few months to complete.*					
9. I finish whatever I begin.					
10. I have achieved a goal that took years of work.					
11. I become interested in new pursuits every few months.*					

I am diligent.					

[K]

Study 2 Script

Stanford Sleepiness Scale (SSS)

Using the following descriptions how do you feel right now?

Thermal Comfort Assessment (TCA)

Using the following descriptions how do you feel right now?

Pittsburgh Sleep Quality Index (PSQI)

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

The Brief Self-Control Scale

Please read the following 13 statements and for each, check the box that best reflects how you typically are.

State Self-Control Capacity Scale

Please read the following 10 statements and for each, check the box that best reflects how you feel right now.

The Delay-Discounting Rate Monetary Choice Questionnaire

For each of the next 27 choices, please indicate which reward you would prefer: the smaller reward today, or the larger reward in the specified number of days. Please answer each question thoughtfully as you will be given the change to be rewarded with one of the money options you choose.

Tracing Puzzle*

(**Do not tell participants this is the final task*) In this task you will be tracing a SERIES of geometric figures. Using the marker and notecards in front of you, trace the shape without lifting your marker from the notecard and without retracing any lines. If you make a mistake while tracing the shape or would like to start over, please take a new notecard before making another attempt. You can take as much time and make as many attempts as you would like. You will not be judged on the number of attempts or the time you take. Once you have successfully traced the shape, OR you choose to move on to the next shape before completing the current one, please inform me (the researcher) and I will present the next shape.

Handgrip task

When you are ready, squeeze the handgrip together as hard and as long as you can. The researcher will instruct you when to stop

Grit Scale

Here are a number of statements that may or may not apply to you. For the most accurate score, when responding, think of how you compare to most people -- not just the people you know well, but most people in the world. There are no right or wrong answers, so just answer honestly.

[L]

<u>Monetary Choice Questionnaire Reward</u>

As part of the Monetary Choice Questionnaire task, participants will answer all 27 questions regarding money amounts. See example below.

1. Would you prefer $54 today, or $55 in 117 days?

[ ] smaller reward today

[ ] larger reward in the specified number of days

2. Would you prefer $55 today, or $75 in 61 days?

[ ] smaller reward today

[ ] larger reward in the specified number of days

3… etc.

At the end of the session, a calculator with a random number generator function will be used to select two numbers. [**TI-89**: Press 2nd MATH. Press 7:Probability. Press 4:rand(enter upper bound) and press ENTER You will see the first random number]

The first number determines whether or not the participant receives any amount at all. If the odds of receiving a reward are 1:4, then the calculator will generate a number from the range of 1 to 4, if the number is a 1, then the participant will receive an amount.

The second number will be the Monetary Choice Questionnaire question number which specifies the amount. The calculator will generate a number from the range of 1 to 27 (the total number of questions on the questionnaire), if the number is a 1 for example (see above), then the participant will receive $54 immediately if they chose SMALLER. Or, the participant will be contacted in 117 days to receive $55 if they chose LARGER. The participant will be told whether or not they were selected for an amount before they leave the lab.